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PREFACE

This paper has been prepared by the Institute for Defense Analyses (IDA) as a deliverable in completion of the Independent Research Project entitled "Military Operations in Urban Terrain." The work for this study was sponsored by IDA's internal Independent Research Project program.

A special thank you is extended to those individuals who shared their time, experience, and insights from real world military operations in urban terrain (MOUT) with the author through interviews, conversations, and correspondence. The author is also grateful for the support, advice, and guidance received from members of the IDA team, which focuses on MOUT and individual combatant issues, as well as the reviewers, Dr. Jeffrey Grotte and Dr. Karen Richter, and the manuscript editor, Eileen Doherty.

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I. INTRODUCTION

Since the mid-1990s, the U.S. military community has focused on improving its understanding of military operations in urban terrain (MOUT). This is partly a result of increasing experience in this environment and partly a reflection of expectations for future military operations in urban areas. However, there does not appear to have been a corresponding degree of interest or study with respect to the effects (costs and benefits) of urban infrastructure, and its disruption.

At the heart of every city are interconnected networks of infrastructure that provide valuable, and some might argue indispensable, services to its inhabitants and the functioning of their daily lives. Infrastructure is what makes an urban area as a whole run in a stable and predictable manner. The importance of infrastructure and its services make it a likely target for control or disruption by either friend or foe in a military operation in an urban area. For example, a city's electricity generation and distribution capabilities provide and deliver a dependable source of power that makes traffic lights, computer systems, etc., operate properly. When infrastructure is disrupted — whether it be due to weather conditions, natural disaster, neglect, or prolonged conflict — its services cease to function or are at least degraded, creating numerous impacts that could affect a military operation and the non-combatants remaining in the city.

Within the literature an occasional statement is made related to power, transportation, communications, water resources, etc., with respect to a military operation, but these have predominately been peripheral comments rather than comments specifically focused on this area of study. This study strives to improve the understanding of infrastructure and the types of impacts that its disruption may have on a military operation and on non-combatants. Also, an approach will be developed for incorporating infrastructure and the effects of its disruption into modeling and simulation (M&S). The ultimate objective is that M&S, with the capability to better portray infrastructure, its impacts, and the urban environment as a whole, could be used by the military community for planning and training to look at different approaches to an urban operation with the goal of optimizing the outcome for both friendly combatants and non-combatants.

A. Purpose and Scope

The purpose of this study is twofold:

1) To identify commonalties in the way infrastructure and its disruption (physically and digitally) have had an impact on military operations and non-combatants,
2) To develop an approach to portraying infrastructure and its impacts in modeling and simulation.

Because infrastructure and military operations in urban terrain are both such vast areas for consideration, this study has limited itself in two ways: 1) the types of infrastructure to be addressed; and 2) the body of military operations' experience from which insights will be drawn. The infrastructure examined will be restricted to transportation networks and power grids, and insights will be drawn from three historical examples of military operations in urban terrain, Mogadishu (1992-94), Grozny (1994-96), and Kosovo (1998-present).

B. Definitions

The intent of this paper is to focus on civilian infrastructure. However, there are instances when military infrastructure, in the form of vehicles, bases, and other assets, also need to be considered. For example, the unavailability of local trucks to haul relief supplies to non-combatants may require the use of military vehicles; the types of military vehicles normally used for personnel and supply transport may be incompatible with the local transportation infrastructure available; or the overall condition of infrastructure in the area of operation may be so poor as to require the use of infrastructure (civilian and/or military) in neighboring areas to support the conduct of the military operation.

The following are definitions of what will be considered, for the purposes of this study, representative of a power grid and a transportation network.

Power grid includes:

- Central power station
- Cross country transmission lines
- Substations
- Wires and cables for distribution
- Step-down transformers
- Cable for connection to building

- Circuits, fused switches, wires internal to buildings, or individual pieces of equipment
- Fuel supply and distribution.

Transportation network includes:

- Transportation vehicles (buses, railcars, subway cars, ships, aircraft)
- Transportation corridors (roads, rails, airfields, airspace, ports)
- Networked power supply (electricity)
- Control/operations centers (dispatch, train station, airports, air traffic control)
- Fuel supply and distribution.

C. A Need for Study

This paper has introduced the need for the study of infrastructure and its impact on military operations in urban terrain, as well as the importance of being able to capture these elements and characteristics in M&S. However, a more detailed discussion of the need for this study can be established by looking at three questions:

- Why a MOUT focus?
- Why improve MOUT M&S?
- Why is infrastructure important?

It is the interaction or intersection of these three questions that sets the stage for the void that this study attempts to address. The following will explain why MOUT has become an important area of interest, how M&S can support the study of MOUT, and how infrastructure plays a vital role in an urban environment and, therefore, should be examined for its impact on a military operation and on non-combatants.

1. Why a MOUT Focus?

There is a need to provide U.S. forces with improved capabilities, training, and approaches to increase their success in MOUT. How and why was this need established?

First, demographic trends indicate that two-thirds of the world population will live in urban areas by 2025. This is not so far in the future that there is the luxury to dismiss consideration of how such population trends will impact the world and future military operations.

Second, one can look around the world and identify where U.S. and foreign military operations have taken place and will likely continue to take place in urban areas. Just a few such examples include Haiti, Sarajevo, Mogadishu, and Grozny. Indeed, unlike in the past when cities were to be avoided, at least partly because that is where the people were, today people seem to have become the mission in many instances. The operations that the U.S. recently has been involved in have tended toward the peacekeeping/law-and-order-enforcing types of missions, which require that the operation take place where the people and/or centers of power reside.

Third, the 1994 Defense Science Board Summer Study formalized the need for a MOUT focus when it recognized that the urban environment is the most likely battlefield of the 21st century, and, furthermore, that the then-current capability of U.S. forces were in potential danger in MOUT.

2. Why Improve M&S?

There is a need for an improved M&S capability to support training, mission planning, mission rehearsal, and the investigation of concepts, doctrine, and systems to enhance U.S. forces' capabilities in MOUT. M&S can be used as a tool to assist in analyzing and reaching a better understanding of how to operate in a MOUT environment. How and why was this need established?

The opportunity for urban field exercises, whether they are for training or analysis purposes, is few. There are only a few urban facilities available to U.S. troops throughout the world at U.S. military installations. In addition, running these exercises requires a substantial time commitment by a unit, and can prove costly.

The data and insights that are gained from the urban field exercises that do take place are also limited by virtue of the size and characteristics of the MOUT facilities in which they are conducted. Existing MOUT facilities do not replicate the size and complexity (i.e., number of buildings, types of buildings, abundance of non-combatants, etc.) of a real-world urban area. The limited size and construction of these MOUT facilities constrains unit sizes that can be exercised and, for safety and practicality purposes, the types of units and weapons that can be employed.

Because of the lack of MOUT training and analysis opportunities truly reflective of real-world urban areas, M&S may prove a cheaper and less time-consuming means for investigating the MOUT environment and its related issues. M&S could provide not a substitute for field exercises, but a way to augment the amount of live MOUT activity that can take place. In trying to better understand MOUT, M&S could be used to explore tactics and weapons that cannot be employed in live exercises, and in conjunction with more complex urban terrain and larger units. M&S can provide more repetition (i.e., it is relatively easy to run multiple iterations once the scenario has been established in the model) to generate greater amounts of statistically significant data with which to explore MOUT. M&S also provides a degree of flexibility (i.e., it is relatively easy to make changes in the established scenario and then run multiple iterations) to investigate different approaches and systems. M&S also has the benefit of being able to be used to exercise commanders, headquarters, and staffs without accruing the expense and committing the time and cost of exercising actual troops.

The 1999 Defense Science Board Task Force examined M&S and recognized that present M&S falls short in its capability to capture some key security environments, such as MOUT. Its final report recommended improving M&S so as to better portray these important features of security environments and human elements.

3. Why is Infrastructure Important?

There is a need to understand and capture the effects of infrastructure and its disruption in M&S in order to improve efforts to explore MOUT. How and why was this need established?

Infrastructure is key to what makes a city tick. Some examples of infrastructure include: power grids, transportation networks, water and sewer systems, garbage service, mail service, media, and communications. Infrastructure provides valuable services to its inhabitants. In a modern, dense urban environment there may even be a higher concentration of physical infrastructure and people who depend on it. As long as infrastructure is functioning properly and delivering its depended upon services, it is likely to go unnoticed. If it is disrupted, however, the daily lives of the city's inhabitants are directly and immediately affected. This impact is magnified by the fact that infrastructure disruption has multiple layers of ripple effects. For example, a disruption in electricity not only means that there are no lights, but also results in no refrigeration, no water, and traffic signals that do not work, which then also produce their own ripple effects that have an impact on the urban population's daily lives. Some examples of ripple effects that might occur due to the disruption of a power grid or transportation network can be found in Tables 1 and 2.

Table 1. Possible Ripple Effects of Power Grid Disruption

First Order Effects	Second Order Effects	Third Order Effects
No light after dark or in building interiors	Erosion of command and control capabilities	Greater logistics complexity
No refrigeration	Increased requirement for power generating equipment	Decreased mobility
Some stoves/ovens non-operable	Increased requirement for night vision devices	Decreased Situational Awareness
Inoperable hospital electronic equipment	Increased reliance on battery-powered items for news, broadcasts, etc.	Rising disease rates
No electronic access to bank accounts/ money	Shortages of clean water for drinking, cleaning and preparing food	Rising rates of malnutrition
Disruption in some transportation and communications services	Hygiene problems	Increased number of non-combatants requiring assistance
Disruption to water supply, treatment facilities, and sanitation	Inability to prepare and process some foods	Difficulty in communicating with non-combatants

Table 2. Possible Ripple Effects of Transportation Network Disruption

First Order Effects	Second Order Effects	Third Order Effects
Degraded use of and/or inoperable airport facilities	Decreased rates of movement	Greater logistics complexity
Degraded use of and/or inoperable seaport facilities	Fewer movement and supply route options	Decreased mobility
Degraded use of and/or inoperable roads	Limitations on the type or number of vehicles that can be used and supported	Decreased access to work, food, essential services
Degraded use of and/or inoperable bridges	Limitations in the types of local support services available	Decreased inflow and outflow of goods, leading to shortages and higher prices
Degraded use of and/or inoperable support services (i.e., air traffic control, off-loading equipment, etc.)	Need for immediate repairs	Greater difficulty in mass movements of people and supplies
Inability to use local vehicles	Need to keep clear routes secure	More non-combatants unable to move from combat area

Since infrastructure affects everyone within the urban environment, it also has the potential to affect a military operation. Its effects are witnessed in two general instances. On the one hand, a military force may find itself deploying to and conducting its operation in an area where the infrastructure is already degraded. The condition of the infrastructure may be due to a natural disaster, neglect, or previous conflict. On the other hand, a military force may be in an area where the infrastructure is still functional and the goal may then become to control infrastructure to one's advantage. In its simplest form, this requires denying use of the infrastructure to the enemy, but also minimizing collateral damage and negative impacts on non-combatants, while facilitating its use for one's own forces.

(a) Degraded Infrastructure upon Entry. The state of the infrastructure (regardless of how it arrived at that state) is an important consideration for any military operation. Many operations other than war (OOTW) and even more traditional missions will require the military to be concerned with urban infrastructure almost solely due to its degraded state at the time of the force's arrival. In these instances, there needs to be a focus on and a better understanding of the impact that these diminished infrastructure facilities and networks have on a military operation, and the efforts needed to mitigate these impacts (both on friendly combatants and non-combatants) and ultimately improve the infrastructure for its eventual transition from military to civil authority.

(b) Control of Infrastructure to Meet Objectives. From a military perspective, control over infrastructure is desirable in order to be able to manipulate, to the degree possible, how that infrastructure impacts a military operation. Having control over infrastructure and the delivery of its services may allow a force to improve its Situational Awareness (SA) or impact logistics in terms of what items are needed and the capability to get these items in the hands of those that need them. A force's mobility (air, land, or sea) and reinforce/re-supply capabilities may also be improved through control over infrastructure. Denying the use of infrastructure to the enemy may be done to slow their responses. Not having access to infrastructure could reduce their SA, degrade mobility, and impede the enemy force's ability to reinforce/re-supply.

Minimizing the negative impact of infrastructure disruption on non-combatants can also serve to benefit the military operation in a number of ways. Minimized negative impacts could translate into a smaller portion of the military effort that has to be diverted to addressing non-combatant needs. Also, human needs and suffering attract the attention and assistance of non-governmental organizations (NGO) and humanitarian relief organizations (HRO), which introduce a new set of players that must be taken into consideration and could add to the complexity of coordinating and executing the operation. Minimizing the impact of infrastructure disruption on non-combatants could, therefore, also minimize the need for or level of NGO/HRO involvement. Ultimately, however, at the end of an operation, there will come a point when the forces will need to leave. Minimizing the degree and types of damage inflicted on the infrastructure during the course of an operation may allow the military a more timely and less costly transition to civil control.

Since the objective is control over infrastructure, its complete destruction is hardly a military operation's only, or most desirable, option. Indeed, the means of influencing infrastructure spans the whole spectrum, from complete physical destruction to limited degradation to temporary physical or digital disruption. Each of these options, however, corresponds to a different degree of overall effect.

Figure 1 presents some examples of the means that could be used to disrupt or gain control over a power grid or transportation network. The overall effect arrow that appears in the center indicates both how lasting an effect is and how disruptive it has been. For example, the physical destruction of a central power station will likely require more effort and time to restore to full operation and will disrupt the lives of a larger segment of the population than the disconnection of individual circuits for a particular building or piece of equipment. Likewise, the impact of the physical destruction of a road/railway/airfield could affect wider segments of the population and could last months, whereas taking control over a particular transportation vehicle might only effect that small number of people who need to use that vehicle at a specific time and place.

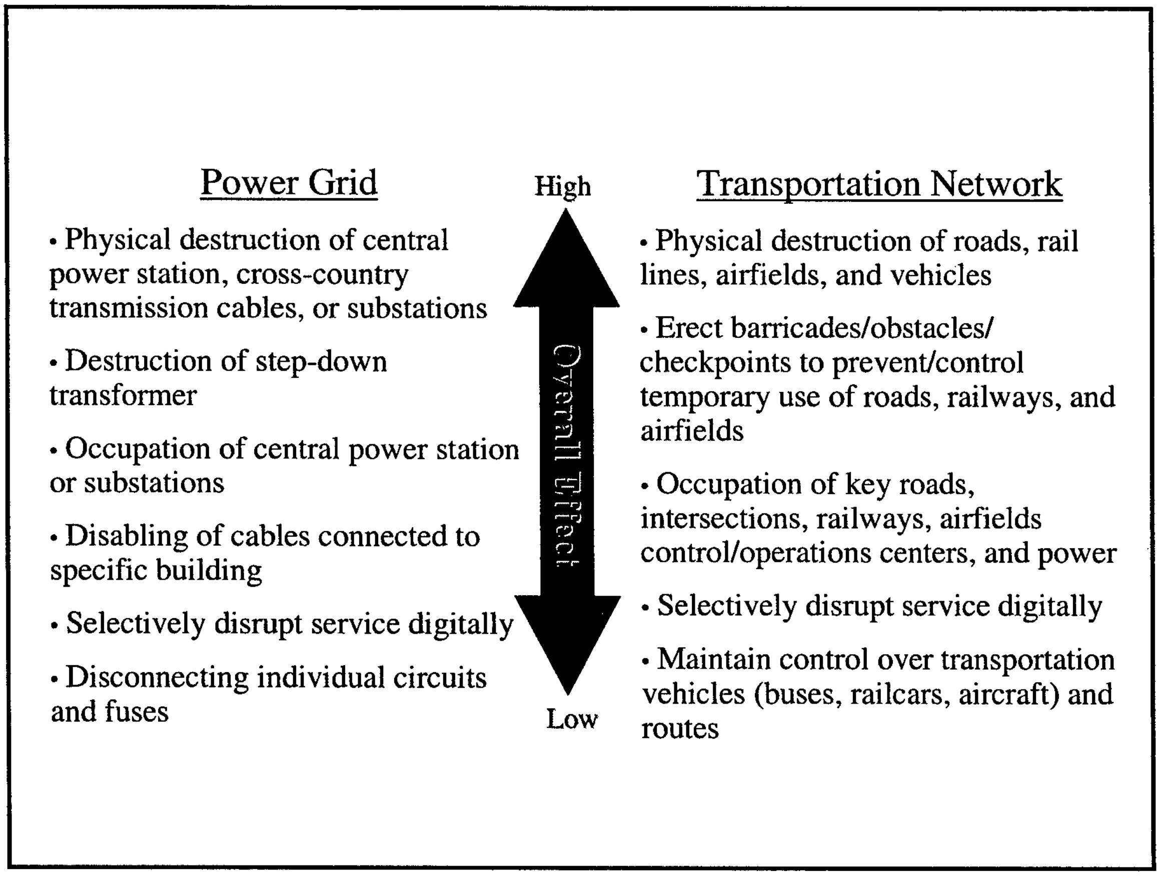

Figure 1. Examples of Means to Gain Control over Infrastructure

4. An Intersection of Needs

With the anticipated growth of city populations, past and present military commitments that include urban areas, and the existence of people-centric missions, it seems highly likely that U.S. forces will be expected to conduct operations in urban areas in the future. This being the case, efforts are needed to ensure that these forces have the capabilities, training, systems, and approaches to improve their chances of mission success in the urban environment.

Having established that MOUT capabilities of U.S. forces need to be enhanced, M&S can serve as one piece of the urban training and analysis puzzle. The closer that M&S is able to portray the reality of the complex MOUT environment and the behaviors of combatants and non-combatants, the more useful it can be in supporting training, mission planning, mission rehearsal, and the investigation of concepts, systems, and approaches to enhance the force in MOUT.

Because of the importance of its status and the services it provides, the impact of its disruption, and the ripple effect that such a disruption can produce, infrastructure affects combatants in a military operation, as well as the everyday lives of non-combatants. Therefore, infrastructure and its impacts are one portion of the MOUT security environment that should be better understood and captured in M&S to support the enhancement of forces in MOUT.

D. Methodology

To better understand the study topic, research began with a review of the literature pertaining to urban warfare and, specifically, infrastructure. This was done, first, to discover how the topic of infrastructure and military operations has been dealt with previously and, second, to assist in identifying historical examples for study. The goal was to identify three historical examples pertaining to fighting in cities and, more specifically, where a military operation affected and/or had been affected by city infrastructure. More in-depth information was then gathered for each of the three chosen examples by further researching relevant source material and conducting interviews with individuals who had either been directly involved or otherwise possessed expertise in the particular urban military operation being studied. From this research, a summary case study was written for each historical example. These case studies were never intended to be comprehensive, but rather were meant to summarize the military activity, describe the state of the infrastructure at the time of the military's arrival in the city and its impact on military operations as well as efforts to improve/mitigate these effects, and identify any insights that can be drawn due to these impacts. These three case studies were then compared to determine if there were any commonalties in the types of impacts experienced in and insights drawn from these historical examples.

To address the M&S portion of this study, the first step was to look at present M&S capabilities to represent urban infrastructure and its impacts. Concurrent with this was an effort to determine measures for subsequent analyses, i.e., to establish the types of outputs from M&S and live field exercises or operations that would allow one to measure the appropriateness or benefit of being able to plan and train with the capability of representing infrastructure and its impacts in M&S. With the understanding of infrastructure characteristics and M&S capabilities, a determination was then made concerning the types of characteristics and impacts of infrastructure that it would be desirable to include in M&S. Finally, an approach was developed for incorporating transportation networks, power grids, and the impacts of their disruption in M&S.

E. Outline of this Paper

Chapter II presents a summary of some of the existing documentation and efforts that captures aspects of infrastructure and a military operation. Chapter III contains case studies for three historical examples of MOUT that were chosen to provide insights on the impact of infrastructure and its disruption. Chapter IV represents the modeling portion of this study and lays out an approach for incorporating infrastructure and its disruption into M&S. Chapter V presents a number of conclusions based on this study and recommendations for future areas of research.

II. CONSIDERATION OF INFRASTRUCTURE

The fact that Chapter I has argued for the need for research that focuses on the impact of urban infrastructure from the perspective of a military operation does not mean that the U.S. military has ignored infrastructure in the past. Several Service and joint publications make at least cursory mention of the importance of infrastructure in an urban area. In particular, World War II (WWII) experiences related to civil affairs may be able to shed some light on approaches used in handling the impact of infrastructure on a military operation and non-combatants. In addition, there recently has been activity by the Services and other government agencies to begin to consider the role of infrastructure in future MOUT conflict or a natural disaster scenario. This chapter will provide several summary examples of how infrastructure has been or is being addressed in several key military documents and other efforts.

A. Service and Joint Publications

1. Army MOUT Field Manual

The Army Field Manual, *Military Operations on Urbanized Terrain (MOUT)*,[1] describes the Army's methods of classification for built-up areas, building and street patterns, urban patterns, and pattern effects, as well as providing information about lines of communications (LOCs), tactical implications, and characteristics of urban warfare. After an initial introduction, it goes into greater detail on MOUT from the perspective of offense, defense, combat support, and combat service.

LOCs are discussed for their importance in allowing for rapid movement and ability to accommodate many vehicles at a given time. These capabilities make them attractive as potential targets for disruption or control for the purposes of gaining the advantage in a military operation. However, the resulting contradiction that is evident in the destruction of an LOC is captured in the following statement: "If these systems can be destroyed, the LOCs may be virtually useless and an obstacle in themselves."[2] This statement indicates a recognition that infrastructure-type targets and the methods chosen to disrupt them have implications for both combatants and non-combatants.

[1] *FM 90-10: Military Operations on Urbanized Terrain (MOUT)*, Washington, D.C. Headquarters, Department of the Army, 15 August 1979.

2. Army Field Manual on Combat in Built-Up Areas

A second Army Field Manual, *An Infantryman's Guide to Combat in Built-Up Areas*,[3] highlights the need for the consideration of infrastructure and its potential impacts during the performance of an urban analysis. The specific types of additional consideration that should be included in these types of analyses include:

> Maps and diagrams of sewer systems, subway systems, underground water systems, elevated railways, mass transit routes, fuel and gas supply and storage facilities, electric power stations and emergency systems, and mass communications facilities (radio, telephone) are of key importance during urban operations. Sewer and subway systems provide covered infiltration and small-unit approach routes. Elevated railways and mass transit routes provide mobility between city sectors, and point to locations where obstacles might be expected. Utility facilities are key targets for insurgents, guerillas, and terrorists, and their destruction can hinder the capabilities of a defending force.[4]

This field manual also contains some more detailed information of relevance to infrastructure in its statements on securing a route and seizing a traffic circle or key objectives, for example, a bridge.

3. Marine Corps X-File on Humanitarian Assistance and Disaster Relief

The purpose of the Marine Corps' *Humanitarian Assistance and Disaster Relief*[5] document is to assist in focusing assessment efforts and defining the role of the military in a humanitarian or disaster relief situation. This has a direct correlation to the topic of this study because of the types of infrastructure disruption that often coincide with humanitarian and disaster relief. "Natural disasters and conflicts affect all parts of the system. The military can sometimes help by making vital, minor, temporary repairs that allow others to provide relief, or provide temporary air transport (especially heavy rotary wing lift)."[6] In order to conduct the assessments that are necessary to determine the desirability of military involvement and its objectives, some examples of key questions are provided for topics relevant to facilities and infrastructure.

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[2] Ibid, 4.

[3] *FM 90-10-1, An Infantryman's Guide to Combat in Built-Up Areas*, Washington, D.C.: Headquarters, Department of the Army, 12 May 1993.

[4] Ibid, 2-6.

4. Joint Task Force Commander's Handbook for Peace Operations

The Joint Task Force Commander's *Handbook For Peace Operations*[7] is a resource available to Joint Task Force (JTF) Commanders planning for or currently involved in a peace operation. Planning for such an operation requires an assessment of the situation to include aspects of the area's infrastructure, including roads and utilities. These assessments are performed by an assessment team, which deploys to the area of operation early to clarify "the mission by actually deciding what needs to be accomplished, what type of force is required to accomplish it, the proper sequence for deployment of the force, availability of in-country assets, and what ongoing operations are being conducted by organizations other than military forces."[8] The composition of this team should include an individual who is specifically able to assess infrastructure and highlight obstacles and opportunities that it can present. This handbook also contains more detailed discussions on civil affairs and logistics support that may be of use in addressing infrastructure issues.

B. WWII Experience

The wealth of knowledge resident in the historical record of U.S. and Allied forces' experience in dealing with civilians during and in the aftermath of WWII is recognized as being of particular interest to this study. Unfortunately, an in-depth exploration of these experiences and lessons learned were beyond the scope of this study, and therefore not incorporated into its insights, conclusions, and recommendations. However, the following is a summary of some areas of the WWII experience that likely merit further consideration in a future study.

The ability of the U.S. and Allied forces to successfully execute the occupation of Germany and Japan and facilitate the necessary reconstruction efforts was the result of an evolutionary learning process conducted during the beginning years of WWII. *Civil Affairs: Soldiers Become Governors* is a special studies volume of the United States Army in World War II series. It "deals with U.S. Army and Anglo-American planning

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[5] *Humanitarian Assistance and Disaster Relief, X-File 3-35.11*, Marine Corps Warfighting Laboratory (MCWL), U.S. Marine Corps, 29 January 1999.
[6] Ibid, 6.
[7] *Joint Task Force Commander's Handbook for Peace Operations*, Joint Warfighting Center, 16 June 1997.
[8] Ibid, I-9.

and operations in the sphere of relations with civilians in certain liberated and conquered countries."[9] This volume details the evolution of the U.S. approach to civil affairs, which established the structure necessary to implement successfully the occupations and facilitate the restoration of their economies and societies.

During the U.S. Army's initial WWII experience in northern Africa, there appears to have been an assumption that the normal civilian authorities and channels would address the needs of civilians. However, it soon became clear that the civilian agencies neither had the capabilities nor the coordination necessary to accommodate civilian needs, and that the military needed "to insure that such activities will not complicate, but actively assist the accomplishment of the military mission."[10]

> The military stores assembled for the operation should consequently include food, medical supplies and housing facilities, based on previous estimates of the condition to be faced. The Military Commander has a special staff section — Civil Affairs — for distribution of supplies, maintenance of order, establishment of municipal and public utility services, and supervision of civil government personnel.[11]

This experience had immediate implications for plans to invade and occupy the enemy territory of Sicily. A high-level War Department agency was established to provide a coordinating element to conduct the necessary planning for the military to be prepared to assume responsibility for civil affairs throughout involvement in WWII. This approach to providing for citizens continued to evolve throughout the war.

The rebuilding and restoration of infrastructure was likely a key component of Germany and Japan's occupations and efforts to reconstruct their economies and societies. Numerous books and documents exist that detail these periods in history and their associated military operations and recovery efforts.

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[9] Harry L. Coles and Albert K. Weinberg, *United States Army in World War II: Special Studies — Civil Affairs: Soldiers Become Governors, Special Studies*, Washington, D.C.: Office of the Chief of Military History, Department of the Army, 1964, ix.

[10] Ibid, 53.

[11] Ibid, 65.

C. Recent and Ongoing Service and Government Agency Efforts

1. U.S. Marine Corps

The U.S. Marine Corps has established itself as a strong proponent for MOUT. This interest in improving their MOUT capabilities and approaches have been expressed in such Marine Corps programs as Urban Warrior and Project Metropolis, and by their participation in the MOUT Advanced Concept Technology Demonstration (ACTD). In addition to these operational programs, the Corps has also shown a willingness to improve its understanding of key features of an urban environment.

From the summer of 1999 through the spring of 2000, the Commanding General of the Marine Corps Warfighting Laboratory (MCWL), in conjunction with the Office of the Secretary of Defense, Net Assessment, sponsored three workshops focused on the vulnerabilities of infrastructure networks to future computer-generated attacks. Each of the workshops gathered participants from the military, government agencies, and infrastructure-related industry. Both power grids and transportation networks were considered.

Several general insights that can be drawn from these workshops, are:

- Infrastructure networks are becoming even more dependent upon computers.[12]
- Infrastructure networks can be interdependent, which can be evident in the types of effects generated by a disruption.[13]
- Disruption of infrastructure can have "unintended consequences" in other areas.[14]
- "Minor degradation of an infrastructure … [may] induce strategic consequences effecting national security."[15]
- Increased complexity of infrastructure systems may impact recovery time.[16]
- There is a need for M&S that can accommodate computer-based attacks.[17]
- Intelligence on infrastructure networks will require significant lead time.[18]

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[12] "Assessment," RMA Workshop— IW Attacks on Critical Infrastructure I, National Defense University, 29-30 June 1999, 4.
[13] Ibid, 5.
[14] Ibid, 8.
[15] Ibid, 9.
[16] Ibid, 10.
[17] Ibid, 24.
[18] "Assessment," RMA Workshop — IW Attacks on Critical Infrastructure II, National Defense University, 29-30 September 1999, 5.

- Disruptions to local and regional infrastructure could have global implications due to connectivity.[19]
- Computer-based attacks may prove more covert and less costly than kinetic attacks.

2. Los Alamos National Laboratory

The Urban Security Team at the Los Alamos National Laboratory has been established with the goal of attaining "scientific competency in urban systems and an ability to simulate the dynamic and complex cities of today and the next millenium."[20] In order to be able eventually to reflect the 'system of systems'-nature of a city, this multidisciplinary team focuses on six areas:

1) urban air-water transport pathways
2) earthquakes and urban infrastructure
3) city recovery and growth
4) airborne toxic release/traffic exposure
5) linked atmospheric and hydrologic modeling
6) framework design.[21]

The intent of the effort on earthquakes and urban infrastructure is to assemble "a set of science- and technology-based computational tools with real-time feedback for disaster planning, training, and management in time of crisis and long-term recovery."[22] Initial work on this has centered around the impact of earthquakes on the power grid infrastructure of the Los Angeles area. The implementation of these tools, developed to analyze the effect of earthquakes on urban power grids, is planned to function as follows:

> "The ground motion predictions are used to estimate damage to the infrastructure-probabilistically at first, but ultimately stochastic algorithms will select a specific set of damaged infrastructure components and create a specific damaged city environment. Dynamic simulations of the damaged linked infrastructures would

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[19] Ibid, 10.
[20] "Urban Security," 1999 Annual Report, LA-UR-99-5554, Los Alamos National Laboratory Web site, http://www.ees.lanl.gov/EES5/Urban_Security/FY99/index.htm, 19 September 2000.
[21] Ibid.
[22] Ibid.

> then illustrate how the earthquake affects the city's ability to function. Within this damaged environment, emergency response scenarios will be simulated to rescue and treat injured people and to restore vital services. Various cleanup, restoration, and recovery alternatives would be explored to rapidly return the damaged city to normal. Analyses of longer term rebuilding alternatives would identify those infrastructure investments that would lead to a more robust, sustainable urban system."[23]

The Los Alamos National Lab example indicates that there is at least one non-military efforts taking place to increase the understanding of infrastructure and its impacts, as well as to provide models and tools for further analysis of this subject. From the summaries of current Service and Joint publications, WWII experience, and ongoing Service efforts, there also appears to be a basic recognition that infrastructure is an important factor in the assessment of an operation prior to deployment. What these military examples lack, however, are any attempt to address the questions of—

- Why or to what extent is infrastructure important to a military operation?
- What are infrastructure's general impacts on a military operation and non-combatants?
- Can different approaches and methods be used to regulate or mitigate certain effects?

The remainder of this paper will attempt to address these questions through the exploration of three case studies and in the development of an approach for incorporating infrastructure and its impacts into M&S.

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[23] Ibid.

III. CASE STUDIES

The following three sections represent summary case studies that were written based on the historical examples of Mogadishu (1992-1994), Grozny (1994-1996), and Kosovo (1998-present). Each consists of three parts: the first contains an overview of the military activity that took place; the second addresses how infrastructure and its disruption have had an impact on the military operation and the non-combatants; and the third presents insights that can be drawn from that particular historical example. A final section identifies the commonalties that exist across all three historical examples.

A. Mogadishu, Somalia (1992 - 1994)

Mogadishu is the capital of Somalia, which is located in the Horn of Africa. Prior to the conflict of the late 1980s and early 1990s, Mogadishu had been a relatively modern city, capable of providing many infrastructure services, such as electricity and transportation, to its inhabitants. It had buildings and structures ranging from refugee huts to steel-reinforced concrete buildings.[24] The population eventually approached 1 million, including refugees.[25]

1. Overview of Military Activity

In 1988, a civil war erupted among the multiple clans that comprise Somali society. "Their culture stresses the idea of 'me and my clan against all outsiders,' with alliances between clans only temporary conveniences."[26] Drought conditions hit Somalia in the early 1990s, which, together with the continuation of fighting between clans, resulted in famine in 1992. With 300,000 - 500,000 deaths and some 800,000 Somali refugees in Kenya and Ethiopia, the international community decided to intervene by providing humanitarian aid, and the military forces to support this activity.[27]

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[24] MG (Ret.) Carl Ernst (Briefing), "JTF-Somalia," Alexandria, VA: Institute for Defense Analyses, 23 May 2000.
[25] Ibid.
[26] Kenneth Allard, *Somalia Operations: Lessons Learned*, Institute for National Strategic Studies, Washington, D.C.: National Defense University Press, January 1995, National Defense University Web site, http://www.ndu.edu/inss/books/allardch1.htm, 3 May 2000.
[27] Robert B. Oakley, "An Envoy's Perspective," *JFQ*, Autumn 1993, 45.

The military operation in Somalia, specifically with respect to the involvement of U.S. forces, can be looked at as having consisted of four distinct phases. A brief summary is as follows.

Phase 1 (April - December 1992): Although the U.S. did not become directly involved until August of 1992, the first phase of activity in Somalia began with the passing of United Nations (UN) Resolution 751, which authorized humanitarian aid and efforts to end the conflict. By mid-summer, the UN's efforts, organized under the United Nations Operation in Somalia (UNOSOM), were proving insufficient, and more airlifts were requested. On 15 August, the U.S. military began *Operation Provide Relief,* with a mission to support the UN's humanitarian relief effort by providing a Humanitarian Assistance Survey Team (HAST) and emergency airlifts of food and other supplies. During this phase, the U.S. averaged 20 sorties and delivered 150 metric tons of supplies a day.[28] However, in conjunction with these enhancements to the relief effort, the security situation continued to deteriorate.

Phase 2 (December 1992 - May 1993): In an effort to continue humanitarian relief work and to get a better handle on the security situation, the UN passed Resolution 794, authorizing a U.S. led coalition, UNITAF. On 9 December 1992, the U.S. began its second phase, *Operation Restore Hope*, a joint- and combined-arms military operation. U.S. military involvement was expanded to secure air- and sea-port facilities and provide security for convoys and relief organizations. "From a JTF viewpoint there was a clear division of labor between the military and HROs [human relief organizations]. The former would create a secure environment in which to deliver supplies by protecting the HRO distribution system, from the ports and airfields where the supplies entered the country, to the road networks over which the supplies moved to distribution points. The latter would get the supplies in country, transport them overland, and distribute them."[29] By early 1993, UNITAF and *Operation Restore Hope* were witnessing noticeable progress: fewer weapons on Mogadishu's streets, less gunfire at night, commerce had

[28] Allard, *Somalia Operations*.
[29] Jonathan T. Dworken, "Restore Hope," *JFQ*, Summer 1995,15.

begun to function again, and "35 dry feeding stations were providing two-kilogram rations to one million people a week."[30]

Phase 3 (May - October 1993): In March 1993, the UN passed Resolution 814 authorizing the organization of UNOSOM II to assume control from and dismantle UNITAF. This resolution authorized the first UN Chapter VII peace enforcement operation, which had the goals of attaining a secure environment throughout the country and assisting in the rehabilitation of Somalia's political institutions and economy. This was "the start of a much bolder and broader operation intended to tackle underlying social, political, and economic problems and to put Somalia back on its feet as a nation."[31] Initially during the UNOSOM II phase, U.S. military involvement consisted of approximately 3,000 troops for Logistical Support and a Quick Reaction Force (1,150 troops from the 10th Mountain Division).[32] A major incident early that summer involving the ambush and killing of Pakistani soldiers by supporters of clan leader General Mohamed Farah Aideed prompted the UN to further evolve UNOSOM II's mission. In response, UN Resolution 837 specifically authorized "the immediate apprehension of those responsible." Within this new atmosphere, clashes continued and led to Task Force Ranger's (Delta Force commandos and a Ranger company) arrival in Mogadishu in August. Task Force Ranger launched a series of raids in search of Aideed and other Somali National Alliance (SNA) leaders. These activities abruptly stopped after the 3rd and 4th of October "Ranger Raid"[33] that resulted in 18 Americans dead and 84 wounded.[34]

Phase 4 (October 1993 - March 1994): Within days of the "Ranger Raid," President Clinton had announced a phased withdrawal of U.S. troops. In the interim, however, they were reinforced and a Joint Task Force (JTF) was established. *JTF-Somalia's* mission was threefold: 1) protect U.S. forces; 2) support UN operations; and 3)

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[30] Oakley, "An Envoy's Perspective," 51.
[31] T. Frank Crigler, "The Peace-Enforcement Dilemma," *JFQ*, Autumn 1993, 66.
[32] Allard, *Somalia Operations*.
[33] For a detailed account of the "Ranger Raid" of 3 and 4 October 1993, see: Mark Bowden, *Black Hawk Down: A Story of Modern War*, Atlantic Monthly Press, March 1999 or on-line at http://www.nightstalkers.com/tfranger/blackhawkdown, 7 September 2000.
[34] Vernon Loeb, "After Action Report," *The Washington Post*, 27 February 2000, W06.

secure lines of communications (i.e., ensure flow of supplies).[35] All of the JTF's activities were conducted in preparation of a 31 March 1994 withdrawal.

2. The Impact of Infrastructure[36]

> "Somalia had primitive airfields, barely usable seaports, disintegrating road networks that did not link population centers, and roadways rendered impassable by fallen bridges and washouts. There was no electricity, no water, no food, no government, and no economy."[37]

a. Power Grid

In the past, Mogadishu had had electrical power capabilities; there was even a wind power facility outside of the city.[38] However, by 1992 and with the arrival of U.S. troops as part of *Operation Restore Hope*, there was no electricity being provided. During the course of the clan fighting (going on since 1988), the copper wiring that carried the electricity had been removed from buildings to sell, in order to get money for weapons.

The following are some of the impacts experienced by *Operation Restore Hope* (December 1992 - May 1993) owing to the absence of a functioning power grid in Mogadishu:[39]

- There was some electricity being powered in Mogadishu; this was in areas or compounds where there were generators. Because only the more well off and politically connected could afford a generator, the existence of generators and the electricity that they produced became a way for the military force to identify those Somalis with political power.
- Bandit and clan activity became very commonplace at night. Because of the darkness resulting from few or no lights, they were able to exploit their knowledge and familiarity of the city, which made nighttime particularly dangerous for the military force and for non-combatants. Because of this activity, some non-combatants

[35] MG (Ret.) Ernst (Briefing), 23 May 2000.
[36] The following section only contains those impacts experienced during Phase 2 and 4 of the Somalia Operation. This is for two reasons: 1) U.S. involvement was most pronounced during these phases, since it was not under the auspices of UNOSOM; and 2) These phases correspond with the times of deployment of the individuals interviewed for the Mogadishu case study.
[37] Joseph P. Hoar, "A CINC's Perspective," *JFQ*, Autumn 1993, 60.
[38] John Allison (Interview), Quantico, VA: Marine Corps Warfighting Lab, 22 May 2000.
[39] Unless otherwise specified, the following information on the impacts of the lack of electricity on operations during *Operation Restore Hope* represents that gathered from: Allison (Interview), 22 May 2000.

felt the need to set up night watches (which could be armed) in order to protect their families and property. The military force, therefore, had to be concerned not only with bandit and clan activity, but also with the existence of at least some armed non-combatants.

- Lighting was used by troops to secure and provide protection to certain areas and facilities. Lights were placed facing out from the military force's position. This proved important to sentries and assisted in identifying where people should go if they needed and wanted help.

- The military force had a tremendous reliance on generators. Generators were needed to provide 24-hour lights and power for headquarters and support. Some problems were experienced with power surges; because of this, there was a need for a good array of generators in order to keep communications going. Also, some difficulties were experienced with computers and printers. This resulted in at least one instance where they resorted to hand-drawing graphics for planning.

- Night vision devices were used in Mogadishu. However, the light clutter in cities, for example from vehicle headlights in a dark street, posed problems with thermal blooming. Because of this, there were occasions when the question was whether it was better to wear the night vision device, or not. Also, in spite of having this capability, night still proved to be a dangerous time.

- The lack of electricity also had an impact on the water supply and there was a shortage of clean drinking water in Mogadishu. The military force needed water to drink, cook, clean, etc., and could not rely on any local water source. This resulted, at least initially, in undertaking the expense and weight of airlifting bottled water into the city. With concerns about water for cleaning and preparing foods, the military force had an increased reliance on meals-ready-to-eat (MREs). The lack of access to clean drinking water also ultimately generated hygiene and health issues for both the force and the general population.

- Another ripple effect of the absence of electrical power was that there was no functioning sewer treatment facility. This served to compound the above-mentioned health and hygiene problems.

- The lack of power also had an impact on communications systems. There was no operating phone system in the city. The infrastructure existed for cell phones, but this was not really considered for any substantial use by military forces. Except for some local radio, there were no public broadcast communications media and the military generally lacked a reliable means for communicating with the non-combatants or with the leaders of the clans.

The following is a summation of the impacts experienced by *JTF-Somalia* (October 1993 - March 1994) due to the absence of a functioning power grid in Mogadishu:[40]

- At the time of the establishment of *JTF-Somalia* in the fall of 1993, individual nodes throughout the city had power. As in the previous Operation, generators were the source of this electricity. By this time, the U.S. force had its own power-generating capability in place and functioning, and really did not consider the absence of power in Mogadishu an issue. There was a ripple effect, however, in that the lack of communications systems meant that there was less to exploit for intelligence-gathering purposes, and there was not a consistent, reliable means for talking to the Somali people and the clan leadership.

b. Transportation Network

Being the capital, Mogadishu had a better transportation infrastructure than elsewhere in the country. It had the country's only international airport; other Somali airfields and facilities remained primitive, often just dirt strips with no indigenous air traffic control capabilities. There was a network of roads that connected coastal cities, such as Mogadishu, with one another, but these were not in good condition and many interior roads were not paved.[41] Mogadishu also had a port facility that had been built by the Russians and was in relatively good shape. Other smaller ports existed up and down the coast of Somalia, but none of these was seriously considered for use in military operations.

The following are some of the impacts experienced by *Operation Restore Hope* (December 1992 - May 1993) due to the poor state of Mogadishu's transportation network.[42]

Air. Initially the Mogadishu airport needed to be made operational. Wreckage from the Somali Air Force had to be removed from the tarmac and even refugees had to

[40] Unless otherwise specified, the following information on the impacts of the lack of electricity on operations during *JTF-Somalia* represents that gathered from an interview with MG (Ret.) Carl Ernst, Alexandria, VA: Institute for Defense Analyses, 25 May 2000.

[41] Allard, *Somalia Operations.*

be relocated from temporary residences they had established at the airport. The airport was assessed by the U.S. Air Force and cleared for flights; however, the airport facilities remained limited. Planes could be refueled, but the operation needed to provide its own air traffic control. Due to these limitations and the dependence on an extensive airlift effort, flights were required non-stop during the first weeks in order to build up the necessary personnel and supplies.

Aside from Mogadishu, the operation had to forge a host-nation agreement with Kenya to use its air facilities in order to support the airlift of humanitarian relief supplies.[43] The Kenyan government was initially reluctant and had to be assured that reimbursement would be made for use and damage incurred. Threat assessments were also made of these facilities so that the necessary security arrangements were in place.

The military force also ran into difficulty in arranging to provide security for the airlift of relief supplies, which were an attractive target for Somali bandits.[44] The International Committee of the Red Cross had a policy that no weapons could be on board aircraft transporting humanitarian relief. This required that a separate "airborne reaction force" travel in conjunction with the relief flights in order to be able to respond if there was trouble once on the ground.

Land. On the ground, the biggest issue with respect to the roads was the restoration of security by cutting down on the presence of "technicals" (jeeps with mounted machine guns used by clansmen) and the use of moveable roadblocks that impeded the movement of people and relief supplies. To gain control over the streets of Mogadishu, the military forces assessed their movement patterns, as well as those of the bandits, in order to determine the placement of checkpoints. Such checkpoints were often established in areas such as markets and traffic circles to maximize control over movement and access to certain areas.

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[42] Unless otherwise specified, the following information, on the impacts of the lack of electricity on operations during *Operation Restore Hope*, represents that gathered from an interview with John Allison, 22 May 2000.

[43] Hoar, "A CINC's Perspective," 57.

[44] Ibid, 57.

The military operation also had to deal with the movement of local drivers who transported supplies for HROs.[45] This was necessary because the local drivers would not drive unless they had a weapon. An identification system was established for HRO truck drivers, which allowed them to carry some weapons and still be able to enter the air- and seaport facilities and pass through roadblocks, etc., which was necessary in order to ensure the movement of supplies.

There was also "Operation Clean Street," an infrastructure building effort to clean up the streets of the city. And there were efforts undertaken involving military forces working with relief organizations to dig wells, rebuild roads, and repair schools.[46] A ripple effect of trying to improve roads was evident when "earthmoving equipment brought in to repair roads and other facilities released tuberculosis spores long dormant in the soil."[47]

There was a significant problem in keeping up with and clearing barricades and roadblocks set up by clan activities. A reconnaissance team could locate a roadblock and by the time a unit with the capability to do something about it arrived, the roadblock would have been dismantled and moved to some other, undetermined location. In one instance, at 8 o'clock in the morning an intelligence activity discovered that the route they had mapped out the night before by air was now obstructed by burning tires, other various debris, and crowds of people.[48]

Sea. Efforts to bring in needed supplies by sea were hindered by Mogadishu's port facility. "Sealift was ... hampered by problems such as a harbor that had not been dredged for more than two years, limited berthing space, sunken vessels in and near the port, a near absence of port services (operational cranes, lighting, electricity) and high sea states."[49] The port was limited to anywhere from one to four ships at a time, due to its turning basin. The port could only be reached at certain times of the day, due to tides, and the operation did not initially have the most current tide data. One Army "materiel prepositioned afloat" ship was not able to off-load at the pier because of the ship's size

[45] Dworken, 17.
[46] Allard, *Somalia Operations*.
[47] Ibid.
[48] Loeb, W06.
[49] Hoar, 60.

and draft.[50] Equipment to off-load ships was mostly inoperable, so all such equipment had to be brought in. "A lack of proper handling equipment restricted cargo flows to 20-foot containers and only permitted self-sustaining vessels to make port calls."[51]

The following are some of the impacts experienced by *JTF-Somalia* (October 1993 - March 1994), due to the poor state of Mogadishu's transportation network.[52]

Air. Unlike previous operations that had set up in Mogadishu proper and at times at the airport, *JTF Somalia* established its headquarters outside of the city. This was done to make the forces less fixed and to have greater freedom of operation.[53]

Land. Unlike the JTF's views on the relative unimportance of the absence of electrical power to its operations, transportation was definitely an issue. Re-opening roads to make sure they were available and secure for the Somali people and UN and U.S. operations was an important part of its mission. In order to gain better control over access to certain areas and the entry of weapons into the city, the JTF co-located units with established UN checkpoints.

In an effort to better understand the Mogadishu road network and lay-out of buildings, as well as to assist in planning, the JTF built its own data base for UUCATS, a force-on-force model of the time. Although only a small portion of the city was eventually available, the model served as a valuable tool in assessing approaches, courses of action, and even the best sniper positions based on maximizing line-of-sight.

Sea. The Mogadishu port remained the major facility for supplies coming into Somalia. There had been a decision early on in U.S. involvement in Somalia to only use the Mogadishu port, and there was some thought that this may have placed limitations on the military and HROs' ability to get the supplies they needed. Furthermore, the emphasis placed on this one port in the capital city made it much more important for the military force to maintain control over this facility, since it was the only in-country seaport facility.

[50] Hoar, 60.
[51] Ibid, 60.
[52] Unless otherwise stated, the following specific information in this section on the impacts of the lack of electricity on operations during *JTF-Somalia*, represents that gathered from an interview with MG (Ret.) Carl Ernst, 25 May 2000.

3. Insights from Experience with Infrastructure

> "Deploying to Somalia was like going to the moon: *everything* needed had to be brought in or built there."[54]

The following are insights that can be drawn from the U.S. military operation's experience, given the condition of the power grid and transportation network in Mogadishu.

Logistics. Arriving in Mogadishu, U.S. forces faced a change in mindset from their Gulf War experience of substantial host nation support. In Somalia, the host nation could not be relied on to provide even the most basic types of support, leaving logistical needs and execution to the deploying force. "From a logistics perspective, Somalia was a nightmare. The ultimate bare-base environment created four primary logistics challenges: projecting major force, establishing airbridge, building expeditionary infrastructure, and managing coalition logistics."[55] The inability of a host nation to provide support, at least partially due to the state of its infrastructure, has implications for a military operation.

The absence of a functioning power grid increased the complexity of logistical support for the U.S. operation in Mogadishu. No electricity translated into increased demand for items such as generators to run lights, computers, and communications systems on a 24-hour basis. The absence of electricity had compromised the water treatment facilities, and therefore bottled water and more MREs were needed due to concerns about using local water for drinking, cooking, and even cleaning foods and dishes. Such items increased the weight and expense associated with the Operation's airlift, and was a contributing factor to the virtually non-stop airlift into Mogadishu's airport for the first several weeks of the deployment. Some of these time and cost pressures of deployment were eased, however, by the pre-positioning of material, predominately on ships.

Despite possessing the best airport, seaport, and road networks in Somalia, Mogadishu's transportation network and facilities were limited in the amount and type of traffic that could be handled at any one time. This resulted in a more protracted effort to

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[53] MG (Ret.) Ernst (Briefing), 23 May 2000.
[54] Joseph P. Hoar, "A CINC's Perspective," 60.
[55] Ibid, 60.

bring in the personnel and supplies necessary to support the military operation. Increased demand was further placed on the already limited airport and seaport facilities, by the additional logistical requirements made necessary due to the absence of electrical power.

Consideration of Neighboring Countries. In order to facilitate the achievement of its objectives, the U.S. force also utilized the air infrastructure available in neighboring Kenya. Therefore, due to the status of the infrastructure in the country where the operation is taking place and/or specific demands of the operation, the force may also need to forge agreements for the use of, and even make the necessary repairs to, the neighboring countries' infrastructure in order to ensure its availability.

Night Vision Devices. As mentioned previously, nighttime proved a particularly dangerous time in Mogadishu due to the absence of consistent or reliable lighting. The U.S. forces' use of night vision devices proved helpful, but more such devices could have been used and, for the most part, night *still* remained dangerous for operations. Also, due to the difficulty that light clutter caused with thermal blooming, thermal night vision devices would have proven better suited for the urban environment. During *JTF-Somali*a and after the October 1993 "Ranger Raid," the absence of electrical power was deemed a military advantage. With the enemy not having access to power, the U.S. force was able to gain superiority in night operations with its use of night vision devices.

Reconstruction. Because of the condition of various infrastructure components, efforts needed to take place immediately to repair and improve certain facilities and to restore services. For this purpose a Naval construction regiment was brought in early on to focus on key infrastructure needs. The first priorities of this construction regiment were the water system and medical facilities.

Communications. Given Mogadishu's electrical power limitations, television and radio were not widely available. This made it difficult for the U.S. force to communicate directly with the Somali people about the Operation. The force also at times had difficulty communicating with Aideed and other clan leaders, which became of vital importance one day when a crowd formed near a U.S. Marine position in the city. Things began to get out of control, as part of a mob mentality rather than any organized clan activity with hostile intent, and could have resulted in the use of force. After this incident, it was decided that a radio, a cell phone, or some other communications device needed to be provided to Aideed so that he could be contacted if the U.S. force ever were faced with a similar situation in which the intent of the crowd was not clear and the use of force considered.

Measures of Effectiveness. In dealing with an operation such as that in Mogadishu that touched upon elements of infrastructure and ranged across the spectrum of conflict, it became clear that some measures of effectiveness (MOEs) needed to be developed in addition to those more traditionally used. For example, one of the major problems that U.S. forces faced in trying to keep the streets of Mogadishu open to traffic was that of temporary obstacles and barricades that could easily be assembled to block a road. A new MOE for how well the operation was doing on any given day was to count the number of barricades that were being seen each day. After more familiarity was gained with these operations, there was also an effort to keep track of what type of barricades (put in place by clans or regular Somali citizens) were being erected.

Urban Intelligence Preparation of the Battlefield. The Intelligence Preparation of the Battlefield (IPB) for Mogadishu was still limited by the time that the *JTF-Somalia* Commander headed to the country at the end of October 1993. During this phase of the operation, the JTF built its own electronic terrain data base for a portion of the city. This gave the U.S. forces the capability to view terrain digitally in a force-on-force model that could then be used for such things as sniper emplacement, by determining various position's line-of-sight. The JTF Commander also mentioned that it would have proven useful to have the location of key infrastructure and its status (i.e., power grid and the status of power [On or Off] in buildings) available in this type of a model.

Limiting Options. Early on in the Operation, there was a decision to use only the port facility in Mogadishu, even though there were other various port facilities up and down the Somali coast. It was suggested that just focusing on the Mogadishu port may have placed limitations on the military operation later on. It may have proven worthwhile to consider other ports, so as not to make access to this facility so critical to maintain and/or so attractive to the enemy.

B. Grozny (1994-1996)

Grozny is the capital of the Republic of Chechnya, located in the Caucasus region of the Russian Federation. Because of its location, Chechnya has long been of geostrategic importance to Russia. Access routes to the Black and Caspian Seas pass through Chechnya, as well as Russian oil and gas pipelines from Kazakhstan and Azerbaijan.[56] "During the last century, Grozny became a major oil-refining center and Chechnya a vital rail, road, and pipeline center for oil transit."[57] By 1994, Grozny was a city of 490,000 inhabitants encompassing approximately 100 square miles. The city consisted predominately of "concrete and brick high-rise apartment buildings" and possessed major air, highway, rail, bus, and tram vehicles and facilities.[58]

1. Overview of Military Activity

The people of Chechnya have a long history of resistance to Russia and its rule. The 1994-1996 conflict was actually sparked in 1991, when the Chechens declared their independence under the leadership of Dzhokar Dudayev during the period of transition following the dissolution of the Soviet Union. A state of emergency was called and Russian troops deployed to the Grozny airport as a show of force with the goal of quickly putting an end to the idea of Chechen independence. However, a stand-off ensued, whereby the Russians were essentially held hostage by Chechen national guard forces surrounding the airport. This situation held until an agreement was reached for the return of the Russian troops in exchange for relinquishing control over Russian ammunition stores in Chechnya to the Dudayev government.[59] A major conflict having been averted at this time, the next two years witnessed increasing civil discontent and attempts to overthrow the Dudayev government, covertly supported by the Russians.[60] After one final and failed coup attempt on 26 November 1994, the Russians decided to adopt a more overt approach to dealing with Chechnya.

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[56] "First Chechnya War— 1994-1996," *Military Analysis Network*, Federation of American Scientists Web site, http://www.fas.org/man/dod-101/ops/war/chechnya1.htm, 15 January 2000.

[57] Lt.Col. (P) John F. Antal, "A Glimpse of Wars to Come: The Battle for Grozny," *ARMY*, June 1999, 30.

[58] Lester W. Grau and Timothy L. Thomas, "'Soft Log' and Concrete Canyons: Russian Urban Combat Logistics in Grozny," Appeared in *Marine Corps Gazette*, October 1999, Foreign Military Studies Office Web site, http://call.army.mil/call/fmso/fmsopubs/issues/softlog.html, 20 April 2000.

[59] Antal, "Glimpse of Wars to Come," 30.

[60] "First Chechnya War— 1994-1996."

Russia's objective in Chechnya was the preservation of Russia's territorial integrity and the restoration of political order, which closely coincided with the need to replace Dudayev's government.[61] Major elements of the Russian operation's plan included the encirclement of Grozny and control of the Chechen borders; the seizure of the Presidential Palace (symbolic of political power) and other key facilities in Grozny; and the stabilization of the city such that authority could be transferred from the Ministry of Defense and the Ministry of Internal Affairs.[62] This Russian plan called for the operation to take place and to be completed within a matter of a few weeks. Indeed, "[a]t the outset of the operation, then Defense Minister Pavel Grachev publicly boasted that he could 'settle' Grozny in just 2 hours with one parachute regiment and subdue all of Chechnya in 72 hours."[63]

Russian planning and thinking centered on the assumption that there would be little Chechen resistance. At the outset, Grozny had a ethnic Russian majority that was generally dissatisfied with the Dudayev government.[64] During ***Phase 1*** (November 1994 - February 1995), however, the Russians conducted bombing missions from the air, leading up to their initial ground assault on 31 December 1994. The indiscriminate bombing of civilian targets quickly built animosity toward the Russian government, which was then directed toward the Russian troops as they advanced on the city.

As they began their attack into Grozny, the Russians encountered a formidable defense mounted by Dudayev-led Chechen rebels and ultimately did not gain control of the city until two months later. Having achieved a degree of control, ***Phase 2*** (March 1995 - August 1996) consisted of a Russian shift of focus toward the pursuit of those Chechen rebels who had fled Grozny, and the further expansion of their control to the countryside and mountainous regions of the Chechen Republic.

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[61] MAJ Raymond C. Finch III, "Why the Russian Military Failed in Chechnya," FMSO Special Study, NO. 98-16, Ft. Leavenworth, KS: Foreign Military Studies Office (FMSO), Center for Army Lessons Learned (CALL), August 1998, 5-6.

[62] MAJ Gregory J. Celestan, "Wounded Bear: The Ongoing Russian Military Operation in Chechnya," August 1996, Foreign Military Studies Office Web site, http://call.army.mil/fmso/fmsopubs/issues/wounded/wounded.htm, 3 January 2000.

[63] Intelligence Production Division, *Urban Warfare Study: City Case Studies Compilation*, Marine Corps Intelligence Activity Publication, Quantico, VA, March 1999, 7.

[64] Interview with Les Grau, Foreign Military Studies Office, Ft. Leavenworth, KS, 23 August 2000.

Phase 3 began 6 August 1996, when Chechen rebels who had secretly filtered back into the city launched an attack against the Russians for control of Grozny. In addition to restoring the dominance of the Chechens in their capital city, this attack ultimately led to a cease-fire and a Russian withdrawal.

2. Impact of Infrastructure

> "The broad central avenue is strewn with glass blasted from bent and twisted windows. Modern high-rises that once housed local dignitaries are scorched, burned-out shells. There is no electricity, no heat, no trams, no medical care, no police, no fire trucks - none of the life lines that keep a 20th century city alive."[65]

a. Power Grid

Prior to the onset of the 1994-1996 conflict, Grozny had been a relatively modern city, providing city services —such as electricity, gas, water — to its just under half a million inhabitants. The Russians do not seem to have specifically targeted components of the electrical grid in order to gain an advantage over their adversary or in other ways influence the outcome of their military operation. In fact, infrastructure as a whole does not appear to have been a primary target initially, as the Grozny television and telephone systems remained operational until several weeks into the bombing campaign.[66]

The absence of a concerted effort or plan by the Russians with respect to the control of the power grid does not mean that electricity was not disrupted. In a conflict, where "[a]t one point, 4,000 artillery detonations per hour were counted in Grozny,"[67] it is difficult to imagine how electrical service could not have been effected. There are reports of an electricity distribution station and a main power plant that were damaged, degrading the capability to produce and distribute electricity in the city.[68] The quote that appears at the beginning of this section highlights the types of devastation that resulted from the bombing, including the loss of electricity. The Russian's use of unsophisticated

[65] "Just Look at What They Have Done to Us," 16 January 1995, Chechen Republic and Amina Network Web site, http://www.amina.com/news/95/95.1.16.html, 1999.
[66] Antal, "Glimpse of Wars to Come," 33.
[67] Intelligence Production Division, *Urban Warfare Study*, 8.
[68] "Russians 'Advance on Grozny'," Grozny, Chechnya, 19 December 1994, Chechen Republic and Amina Network Web site, http://www.amina.com, 1999.; and "Gunfire Crackles in Grozny, Electricity and Water Supply Reduced," Grozny, Chechnya, 18 August 1995, Chechen Republic and Amina Network Web site, http://www.amina.com/news/95/95.8.18.html, 1999.

bombs and at times seemingly indiscriminate bombing practices resulted in significant collateral damage, including the disruption of electricity in at least portions of the city.

The following are some of the impacts experienced by the Russian troops and Chechen rebels, due to the disruption of the power grid in Grozny.

- In general, the Russians did not like to operate at night and as such did not move at this time.[69] Chechen rebels, on the other hand, capitalized on the cover of darkness and perhaps their superior knowledge of the city to move in close to Russian positions at night in efforts to unnerve the troops.[70]

- To combat the difficulties of darkness, the Russians used night vision devices and other methods of lighting, but not without difficulties. There were insufficient supplies of night vision devices. This likely thus degraded their ability for combat identification and reduced their mobility, contributing to their general discomfort with night operations. Use of other lighting also posed its own problems. "[S]ome units used vehicle headlights and other visible light sources to conduct night operations — a tactic explicitly forbidden in army directives. Such use of headlights and searchlights was initially rationalized as a means to shock Chechen forces. Instead, it made Russian forces more vulnerable to counterfire."[71]

- Disruptions in electricity had a ripple effect which contributed to the unavailability of clean drinking water, affecting both combatants and non-combatants. The Russian logistics system broke down on the outskirts of the city and was unable to provide adequate quantities of items such as water and food forward into the city to its troops, let alone to the civilians of Grozny.[72] "Just to get water, residents must wait until the shooting diminishes, then race to the shores of the Sunzha River flowing through the city center, punch holes in the ice and haul up buckets."[73] No running water, the incapacitation of water treatment facilities, difficulties in disposing of bodies, and a shortage of clean drinking water further influenced the occurrence of disease. "Russian soldiers frequently lacked clean drinking water, clean clothing, hot rations and washing facilities. Personnel suffered from viral hepatitis, cholera, shigellosis, enterocolitis, diphtheria, malignant anthrax

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[69] Interview with Mr. Tim Thomas, Foreign Military Studies Office, Ft. Leavenworth, KS, 24 August 2000.
[70] Ibid.
[71] Intelligence Production Division, *Urban Warfare Study*, 14.
[72] Interview with Grau, 23 August 2000.
[73] "Just Look at What They Have Done to Us."

and plague."[74] In one instance, disease, predominately brought about by unclean water, rendered a brigade combat-ineffective.[75]

- The indiscriminate bombing of Grozny not only killed civilians, but indirectly affected them by disrupting valuable services — for example, electricity, heat, water. These types of impacts on daily lives likely contributed to growing animosity toward the Russian troops, which manifested in efforts to impeding the movement of troops or in some cases even joining the Chechen rebels.

b. Transportation Network

Over the years, Chechnya had developed the transportation networks necessary to support its vital role in oil transit and refining in the Caucasus region. The rail system ran between Grozny and the Chechen border, and two airports serviced the capital. Being a large city, Grozny had an extensive road network that included 123 roads leading into and out of the city.[76] Since Grozny is located inland, seaport facilities were not an issue. Water transport was not a factor for either the Russians or the Chechens, but both sides did attempt to control the use of multiple bridges traversing the Sunzha River, which divides the city.

The following are some of the impacts experienced by the Russian troops and Chechen rebels, due to the disruption of the transportation network in Grozny.

Air. As early as August 1994, Russia had conducted air operations to "'close' Chechen airspace to ensure that further mercenaries, weapons, or ammunition were not airlifted into Chechnya."[77] Then on 1 December 1994, the Russians began their bombing campaign with the first objective to target and destroy the Chechen air force and air defense capabilities.[78] Having accomplished this, the Russians eliminated the opportunity for Chechen air mobility and an organized air threat throughout the course of the conflict.

Without air assets to combat the Russians, the Chechens did what they could to limit the Russians' air mobility. Although it is not known how effective it was, one such

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[74] Grau and Thomas, "'Soft Log' and Concrete Canyons."
[75] Ibid.
[76] Briefing by Tim Thomas, Command Post of the Future Workshop, IDA, Alexandria, VA, 18 January 2000.
[77] Intelligence Production Division, *Urban Warfare Study,* 14.
[78] Antal, "Glimpse of Wars to Come," 31.

method was psychological. "Chechens warned that they knew the names of pilots who were bombing them, their addresses, and the names of their family members, all designed to intimidate pilots into avoiding flying. Officers' families, whether ground troops or pilots, received threatening phone calls warning the father not to fight or bomb Chechens."[79]

During the buildup to the ground assault into Chechnya, the Russians established their base at Mozdok in the neighboring Republic of North Ossetia. The existing airbase facilities at Mozdok, as well as Beslan and Vladikavkaz, were used to airlift troops.[80]

After the Russians had established their control over Grozny in late February 1995, they were able to use Grozny's airport facilities to bring in supplies both by airplane and helicopter.[81] In general, however, this air infrastructure was used to bring in only those supplies that were most urgently needed and to fly out bodies for burial.[82] Although generally used in these limited functions, having the ability to quickly fly in items was of great importance to the Russians, as troops were frequently deployed without vital equipment;[83] they often were taken from multiple units and often times not with their unit commanders. Because of systems that hold commanders responsible for their unit's equipment, the commanders were reluctant to send equipment along with the troops deploying separately to Chechnya. Therefore, some Russian troops arrived without flack jackets (important for the urban fight), gloves (important due to winter weather conditions), and spare parts (necessary in larger quantities because of increased maintenance rates caused by urban combat).

Land. Ground-based transportation networks were crucial to Russian logistics and mobility. Because Chechnya is a part of the Russian Federation, Russia was able to rely on many of its own road and, especially, rail networks in order to bring supplies and personnel to its base in Mozdok. To support long distance logistics, "Railroad troops had

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[79] Timothy Thomas, "The Caucasus Conflict and Russian Security: The Russian Armed Forces Confront Chechnya, III. The Battle for Grozny, 1-26 January 1995," appeared in *Journal of Slavic Military Studies*, vol. 10, no. 1 (March 1997), pp. 50-108, Foreign Military Studies Office Website, http://call.army.mil/call/fmso/fmsopubs/issues/chechpt3.htm, 3 January 2000.
[80] "Russian Air Attacks on Chechnya Seem to Have Failed," Grozny, Chechnya, 11 January 1995, Chechen Republic and Amina Network Website, http://www.amina.com, 1999.
[81] Interview with Thomas, 24 August 2000.
[82] Ibid.

to restore 260 kilometers of track, clear mines from another 70 kilometers, repair switches, and restore electric power to electric rail lines."[84] Additional "depots, supply dumps and supply points" were set up reaching out from Mozdok toward Grozny, as well as truck lines of communication corresponding to each of the three approaches to their attack on Grozny, in order to facilitate reinforcement and re-supply.[85] At the height of the battle, 6700 trucks were needed to transport supplies to troops.[86]

Once trucks reached the city limits, however, Russian logistics experienced particular difficulties. Many vehicles — supply, fuel, and water trucks and mess trailers — were vulnerable to attack in, or even had difficulty traversing the thawing ground on, the outskirts of the city.[87] As a solution to this, the Russians pulled BTR-80s from the front lines of the fight in order to be able to provide armored transport of crucial supplies such as water, food, fuel, and ammunition.[88] Not only did this remove armored protection from troops in the city, but these vehicles were only able to ferry a limited amount of supplies to them. Therefore, despite Russian plans to provide troops with more food rations than usual in order to compensate for the intensity of the urban fight, many soldiers had little choice but to eat "dry rations," and ended up consuming far fewer than "the minimum daily required amount of calories."[89] This inability of the transportation infrastructure to support Russian logistics, particularly in the transport of sufficient food and clean drinking water, was a contributing factor in the declining health and rate of disease of Russian troops.

The Chechens used several means to further frustrate the delivery of Russian supplies and the movement of troops. Initial movement of troops along three axes toward Grozny were slowed by civilian protests and blocked roads. In surrounding urban areas, corresponding to the Russian three-pronged attack, the Chechen rebels set up blocking positions and executed supporting attacks to impede the reinforcement and re-supply of

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[83] Interview with Grau, 23 August 2000.
[84] Grau and Thomas, "'Soft Log' and Concrete Canyons."
[85] Ibid.
[86] Ibid.
[87] Ibid.
[88] Interview with Grau, 23 August 2000.
[89] Grau and Thomas, "'Soft Log' and Concrete Canyons."

Russian troops.[90] They also used snipers, mines, and roadblocks as means for restricting Russian access to or slowing movement in a particular area. Within the city limits, the Chechens were also able to misdirect or disorient the Russians — unfamiliar with the city and equipped with poor quality and inadequate scale maps — by altering or removing certain street signs.[91]

The Chechen rebels' plan for the defense of Grozny consisted of three rings, two of which were designed to establish defensive control over various aspects of the transportation network. The outer ring set up a defense in the south and east on the Grozny-Mozdok and Dolinsky-Katayama-Tashkala freeways.[92] The middle ring of defense corresponded to various entrances to highways and bridges over the Sunzha river.[93] The inner ring was centered on the area of the Presidential Palace within the city. Chechen execution does not, however, seem to have necessarily adhered to this three ring defense. Instead, they adopted a mobile strategy that included trapping and ambushing the Russians. As a Russian column entered an area where the rebels were waiting, the Chechens would obstruct both the exit and entrance of a city block, trapping the troops and their vehicles. Once in this vulnerable position, with no opportunity for forward movement or retreat, the Russian troops became easy targets for Chechen fire.

During the initial few months corresponding to Russia's assault on Grozny, the ability of the Chechen rebels to reinforce and re-supply appears to have continued with limited interruption. Since the Russians did not initially encircle Grozny, the rebels were able to move in and out of the city, along with necessary supplies, from the south. This movement of both rebels and civilians to and from the south was accomplished through multiple means, including cars, buses, trucks, and even walking. The Chechens also were able to draw on the established reserves of the Shali Tank Regiment available via the Baku highway between Shali and Grozny.[94] Because of this, logistics really did not become a difficulty for the rebels until they fled Grozny into the countryside.

[90] Interview with Aslan Maskhadov, Marine Corps Intelligence Activity, June 1999, 16.
[91] Interview with General-Major Tourpal-Ali Kaimov, "On Urban Warfare in Chechnya," Marine Corps Intelligence Activity, June 1999, 5.
[92] Antal, "Glimpse of Wars to Come," 34.
[93] Ibid, 34.
[94] Interview with Colonel Husein Iskhanov, Marine Corps Intelligence Activity, June 1999, 22.

Movement of the rebels was also facilitated by their knowledge of the city and their ability to move among the civilians still remaining. If the Russians set up a roadblock on a main road, the rebels could often move by foot along secondary routes.[95] Where a checkpoint could not be avoided, the rebels would instead rely on a public means of transportation, such as a bus, rather than individual cars or taxis, in order to take advantage of the crowd cover that civilians could provide.[96] Civilians also were used "to watch and report any changes — for example a change in the position of a roadblock, any movement of troops and weaponry, and unusual movement or development," specifically with respect to routes that had been previously identified as possible movement routes for the Chechen rebels.[97]

With the Sunzha river running through the city, movement to and from the two sides of the city relied upon bridges. By bombing five bridges during its initial air assault in December 1994[98], the Russians may have been trying to limit the options of the Chechen rebels for crossing the river. After the Chechens were forced to abandon their headquarters in the basement of the Presidential Palace in the center of Grozny, they retreated across the Sunzha river, blowing up as many bridges as possible and setting up a defensive position on the one bridge on a main road that they could not destroy.[99] As the Russians did not use their APCs to traverse the river, this defensive position held until the Russians were able to use a bridge further along the river and move in on the rebels.[100]

3. Insights from Experience with Infrastructure

The following are some insights that can be drawn from Russian and Chechen experiences with the disruption of the power grid and transportation network in Grozny.

Not Targeting Infrastructure. The decision of the Russians not to specifically target infrastructure (such as the power grid and transportation network) may have been based on the belief that this conflict would be brief. With infrastructure intact or at least only minimally damaged, the re-establishment of normal city functions and the daily

[95] Interview with Said Iskhanov, Marine Corps Intelligence Activity, June 1999, 5.
[96] Ibid, 5.
[97] Ibid, 4.
[98] "Russians 'Advance on Grozny.'"
[99] Interview with Colonel Husein Iskhanov, 9-10.
[100] Ibid, 10 and 12.

lives of citizens would be easier and quicker to achieve. Also, Chechnya is a part of the Russian Federation, so it was recognized that Russia would likely be responsible for funding the restoration of infrastructure and the Chechen economy.[101] Seeking to minimize damage to infrastructure can be seen as a way to contribute to a less costly and quicker transition from military to civilian control after the cessation of hostilities. Despite the intent to limit damage, however, indiscriminate bombing and the use of inappropriate ordnance (i.e., causing high collateral damage) in the end resulted in Russian destruction of the infrastructure. In a situation such as this, there is the need for good planning, an organized procedure for identifying and vetting targets, and the availability of weapons capable of producing the desired effects.

Mobility and Combat Identification. The Russians did not like to move or conduct operations at night, whereas the Chechens' familiarity with the city may have allowed them to continue to move when it was dark. The darkness that resulted due to power outages can cause disadvantages in mobility. Combat identification of friend and foe is also degraded by losses in electricity. Compounding these losses, efforts to counteract the loss of light may inadvertently increase one's vulnerability, as witnessed in the use of headlights and searchlights by some Russian troops.

Night Vision Devices. The Russians had night vision devices, but not enough to go around. Having an adequate supply and the optimum type of night vision device for urban combat may improve the troops' overall level of comfort in conducting night operations.

Influence on Civilians. Inhabitants of a city depend on, and to some extent may expect, certain services such as electricity and the use of transportation networks for the conduct of their daily lives. The indiscriminate bombing of civilian areas that result in the disruption of infrastructure may contribute to growing animosity among civilians toward those who are carrying out the bombing.

Logistics. The disruption of electricity has ripple effects that impact the availability of clean water and, especially during the winter months, heat. Logistics is

[101] "Berezovsky Says Federal Budget Funds Must Restore Chechnya," Moscow Russia, 20 January 1997, Chechen Republic and Amina Network Web site, http://www.amina.com/news/97/97.1.20.html, 1999.

affected due to increased demand for bottled water, heating/cooking fuel, blankets, warm clothing, etc. If the logistics system is not prepared and/or is incapable of providing those additional items made necessary by the loss of services such as electricity, in addition to the increased demand generated by the urban fight, then the health of troops and civilians will likely be negatively affected.

Urban fighting, in and of itself, places a strain on military logistics systems due to increased demand for ammunition, food, and other supplies needed to sustain the force. Russian logistics relied heavily on trucks to ferry supplies to support the fight in Grozny. However, "Supply trucks were soft-skinned, not rugged enough and could not be exposed to urban combat. One of the major problems supplying forward forces was that trucks could only go forward to a certain point."[102] An armored supply vehicle would have proven useful by allowing supplies to be delivered into the city without having to divert other armored vehicles not designed for this purpose from combat. Such vehicles would also be able to carry more and therefore meet more of the forces' needs, ultimately contributing to its combat capabilities.

Consideration of Neighboring Areas. The Russians relied heavily on the use of transportation in areas adjacent to Chechen territory. In fact, their main headquarters was in Mozdok in a neighboring republic. The successful execution of an operation may require the use of or be influenced by neighboring areas' infrastructure networks.

Non-military Assistance. It would appear that not much thought was given to providing care for civilians. First, the Russians felt that the conflict would be swiftly settled. Second, they were adhering to the World War II paradigm in which the city would be empty and those who were left would fend for themselves.[103]

In reality, many civilians stayed, including ethnic Russians who tended not to have relatives in the country to rely on and therefore remained in Grozny, enduring hardships caused by disruptions in electricity and shortages of water and food.[104] As the

[102] Grau and Lester, "'Soft Log' and Concrete Canyons."
[103] Interview with Grau.
[104] Timothy L. Thomas, "The Caucasus Conflict and Russian Security: The Russian Armed Forces Confront Chechnya, Part One, Section Two: Military Activities of the Conflict During 11-31 December 1999," appeared in *Slavic Military Studies*, vol. 8, no. 2, June 1995, p. 257-290, Foreign Military Studies Office Web site, http://call.army.mil/call/fmso/fmsopubs/issues/chechpt2/htm, 3 January 2000.

conflict continued, whether ethnic Russian or Chechen, civilians in Grozny had the same needs as the troops — water, heat, blankets, warm clothing. However, with a logistics system already strained by the increased demands of urban fighting and transportation limitations, the Russian military was not able to adequately provide for its troops, let alone the civilians.

The Ministry of Emergency Situations (EMERCOM) assumed the role of dealing with civilian issues and restoring vital services. EMERCOM established water distribution locations, provided heaters, monitored food supplies, and "further restored more than 50 kilometers of high-voltage power lines; restored three heat and power plants; and set up eight diesel electric stations and repaired another."[105] Assistance was also provided by international sources, including $2.5 million from Canada primarily for "critically required basic necessities, including children's clothing, blankets, candles and food."[106]

Blending in with Civilians. In a city where many civilians remained behind during the fight, there is the potential for the indigenous combatant to use its familiarity with the city and its citizens to blend into the crowd. In this way, combatants may be able to capitalize on mass transportation, such as buses to move throughout the city in virtual anonymity.

C. Kosovo (1998-present)

In a number of ways compiling a summary case study on Kosovo proved to be more complex than the previous two case studies. First, the Kosovo conflict and its related military operations do not involve merely two discrete sets of combatants, but rather several, with varying degrees of involvement in the phases of the conflict and its aftermath. Second, unlike Mogadishu and Grozny, the conflict in Kosovo did not key on any one urban area; it ultimately encompassed bombings of Serbia in addition to the ground fighting taking place in Kosovo proper. And third, as will become apparent later, assessing the condition of Kosovo's infrastructure after the cessation of the fighting is complicated, because its status is due to a combination of the effects of ground combat,

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[105] Grau and Lester, "'Soft Log' and Concrete Canyons."
[106] "Canada Announces Humanitarian Aid Arrives in Chechnya," Grozny, Chechnya, 17 March 1995, Chechen Republic and Amina Network Web site, http://www.amina.com/news/95/95.3.17.html, 1999.

bombings, and years of neglect. The following case study attempts to address the above-described layers of complexity.

Kosovo is a region in the southern portion of the Federal Republic of Yugoslavia (FRY), flanked by Albania and the Yugoslav region of Macedonia in south-eastern Europe. Kosovo is of particular cultural significance to the Serbs of Yugoslavia because it is the location of many Serb Orthodox monasteries and the Kosovo Plain, where Serbs battled and were defeated by the Ottoman Turks on 23 June 1389.[107] Despite its symbolic importance to the Serbs, prior to the outbreak of hostilities in the 1990s, ninety percent of Kosovo's roughly 2.2 million inhabitants were ethnic Albanian. Kosovo is a traditionally poor region of Yugoslavia and its "[e]conomic activity had centered on electric power, mining and metallurgy, construction materials and agroprocessing."[108] A majority of its population is rural, but Kosovo enjoys large urban areas, including Kosovska Mitrovica, Gnjilane, Prizren, Pec, and its capital and largest city, Pristina, which had a pre-conflict population of about 400,000.[109]

1. Overview of Military Activity

In 1990, Kosovo had its autonomous status revoked and it was placed under the authority of the centralized, Serb-dominant power emanating from the FRY capital, Belgrade, and represented by its President, Slobodan Milosevic.[110] In response to this, the Kosovar population, predominately in the urban areas, embarked upon several years of peaceful protest. ***Phase 1*** of the Kosovo conflict began in 1998, when "years of non-violent protest against the Serb regime gave way to widespread KLA [Kosovo Liberation Army] guerilla attacks in March, which triggered a government counter-offensive over

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[107] "Kosovo Background," Federation of American Scientists Web site, http://www.fas.org/man/dod-101/ops/kosovo_back.html, 8 December 1999.

[108] "Information about Kosovo," Economic Reconstruction and Development of South East Europe, European Union/The World Bank Web site, http://www.seerecon.org/Kosovo/KosovoInformation.htm, 7 April 2000.

[109] United Nations Interim Administration Mission in Kosovo, "Pristina Central Heating Plant Started Up Today," *Press Release*, 27 November 1999, United Nations Web site, http://www.un.org/peace/kosovo/press/templ.pr.101.html.

[110] Disaster Response Unit of Inter Action, "Kosovo: A Guide to the Relief and Development Efforts of InterAction Member Agencies," *InterAction*, 30 April 1999, Relief Web Web site, http://www.reliefweb.int, 15 June 2000.

the summer."[111] The immediate result of this fighting was the displacement of roughly a quarter million ethnic Albanians. Because of the nature of the conflict and the pending humanitarian crisis that it was generating, the North Atlantic Treaty Organization (NATO) closely observed what was taking place and in June began to formulate a series of options for a NATO response to the conflict. In October, NATO issued an Activation Order for air strikes. However, on the same day and prior to any NATO military action, a cease-fire was reached and the Organization of Security and Cooperation in Europe (OSCE) began a Verification Mission to distribute humanitarian aid, assist in the return of the refugees, and monitor the activities of the KLA and the Serb backed forces.

Phase 2 may be seen as having commenced in January 1999, when the situation in Kosovo escalated. The following month, the first of two rounds of negotiations convened in Rambouillet, France, to present "proposals for an equitable and balanced agreement on interim self-administration for Kosovo."[112] Although at one point agreement appeared to have been reached at least "in principle" by both the Kosovo Albanian delegation and FRY government representatives, the efforts for a negotiated settlement ended on 19 March, when the FRY Serbs refused to accept and sign an agreement.

The disintegration of the Rambouillet negotiations marked the transition into ***Phase 3***. The OSCE verification members and other NGO/HRO workers were pulled out of Kosovo and on 24 March, 1999, NATO initiated *Operation Allied Force* and launched its first air strikes on Serb military targets. The objectives of this operation's air campaign were to cause the Milosevic FRY government to accept the following:

- "a verifiable stop to Serbian military action in Kosovo;
- withdrawal of Serbian forces;
- an international military force in Kosovo;
- refugee return;
- acceptance of political framework based on Rambouillet."[113]

[111] Kurt Schork, "Refugees in forest track Kosovo talks by radio," *Reuters*, 12 October 1998, Relief Web site, http://www.reliefweb.int, 16 June 2000.
[112] Lord Robertson of Port Ellen, "The Crisis Unfolds," *Kosovo: An Account of the Crisis*, British Ministry of Defense Web site, http://www.kosovo.mod.uk/account/crisis.htm, 28 August 2000.
[113] Lord Robertson of Port Ellen, "The Politico-Military Interface," *Kosovo: An Account of the Crisis*, British Ministry of Defense Web site, http://www.kosovo.mod.uk/account/politico.htm, 28 August 2000.

Although it was originally thought that NATO air strikes would quickly bring about a settlement, the actions of the Serbs against the ethnic Albanians of Kosovo actually intensified in the following months. The Serb's goals in 1999 appeared to have been two-fold : "crushing the rebel Kosovo Liberation Army and permanently changing the ethnic balance of Kosovo by driving out as many Albanians as possible."[114] This new wave of activity included efforts to remove ethnic Albanians not only from the rural areas (the traditional centers of the KLA movement), but also from the urban areas, including Pristina. In April, in response to the Serbs continued persecution of the ethnic Albanians, NATO's "target list expanded into so-called sustainment targets – petroleum, lines of communication, electrical grids, and command and control targets."[115] Milosevic finally accepted the peace terms on 3 June, but not before having successfully displaced (some within Kosovo and others in neighboring Albania and Macedonia) ninety percent of the ethnic Albanians from their homes.

The NATO air campaign came to a stop on 10 June in Kosovo. During ***Phase 4***, the United Nations Mission in Kosovo (UNMIK) assumed the administration of Kosovo and the need for Kosovo Force (KFOR), a NATO ground component to maintain security and support UNMIK's mission of restoring stability, was initiated. Kosovo was to be divided into three zones to be headed up by the U.S., Britain, and France as part of KFOR, but ultimately ended up integrating forces from many other countries, including Russia. By September there were just under 50,000 troops deployed under KFOR, where the military forces continue to support UNMIK.

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[114] John Kifner, "Horror by Design: The Ravaging of Kosova," *The New York Times*, date unknown, Albania Net Web site, http://www.alb-net.com;443/pipermail/kcc-news/1999-June/000081.htm, 28 August 2000.

[115] "Operation Allied Force, Operation Noble Anvil," Federation of American Scientists Web site, http://www.fas.org/man/dod-101/ops/allied_force.html, 8 February 2000.

2. Impact of Infrastructure

a. Power Grid

Even before the conflict erupted in 1998, Kosovo's power grid was not being adequately maintained. As an example, the Kosovo power plant located near Pristina, known as Kosovo A, had not been maintained in 10 to 15 years.[116]

Although it is not clear whether the Serbs or the KLA specifically targeted the electrical grid for disruption, by the summer of 1998 there are numerous reports of power outages in villages and cities across Kosovo. In an assessment on behalf of the European Commission, it was found that "Electricity has been disconnected to many villages during the conflict. In some cases, the LV network needs repair and some transformers have either been removed or destroyed by gunfire. It appears also however that some towns and villages were disconnected by the simple expedient of knocking out the higher voltage transmission lines thus denying power to a wider area without causing damage at the house or village/community level."[117]

The Serb paramilitaries, government forces, and KLA may not have consciously sought to disrupt the power grid by attacking power plants, transformers, power lines, etc., but there does appear to have been a realization of the strategic importance of gaining control over coal resources. Both the KLA and Serbs contested for control over the Belacevac coal mine, located six miles west of Pristina, which provides the fuel necessary for running two power plants.[118]

NATO initially focused strictly on military targets, but a month into the air campaign this was expanded to encompass those targets determined as being linked to Milosevic and the Serb's command and control system. This opened targets up to basic types of infrastructure, such as the power grid. Unlike most of the activity by the Serbs and KLA which took place within Kosovo proper, NATO's approach toward the power grid centered on Serbia in an effort to negatively influence public opinion of Milosevic.

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[116] United Nations Interim Administration Mission in Kosovo, "SRSG Visits Kosovo A and Kosovo B Power Plants," *Press Release*, 4 January 2000, United Nations Web site, http://www.un.org/peace/kosovo/press/templ.pr.122.html.

[117] International Management Group, *Kosovo: Emergency Assessment of Damaged Housing and Local/Village Infrastructure*, European Commission, July 1999, 7.

In May of 1999, NATO launched the first in a series of attacks on the "transformer yards of the Yugoslav power grid."[119] The initial strikes were conducted with graphite bombs that created shorts in the system, causing temporary disruptions to power in FRY's major cities, but the power grid was ultimately completely shut down later that month.[120]

Once the U.S. troops associated with KFOR were ready to move into the eastern sector of Kosovo, Camp Bondsteel was built as the base camp. The decision to build a new facility was made, because occupying other already available facilities, such as various industries or schools, would have only impeded progress in the restoration of infrastructure necessary to restore normalcy in Kosovo.[121]

The following are some of the impacts experienced by combatants and non-combatants due to the disruption of or control exercised over the power grid in Kosovo and FRY.

- During research for this case study, no information was found that detailed how the disruption of electricity may have had an impact on the conduct of either the KLA or Serb military operations. In addition, during the phases that encompassed air strikes, neither NATO nor the U.S. had troops located on the ground who would have personally encountered the effects of electricity disruption during the course of the conduct of their mission.
- NATO's hits on the power grid affected "[e]verything from computers which run a country's banking system to the systems which operate air-defense radar stations" to Belgrade's entire command and control structure.[122] The disruption of the power grid played at least a contributing role in bringing about a cease-fire and Milosevic's eventual agreement to the proposed terms of Rambouillet. Having no electricity disrupted the daily lives of FRY citizens and eroded Milosevic's support among the populace. Thus, the bombing of the power grid also helped influence the decisions and agreements of the FRY government, which were necessary to end NATO's air campaign.

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[118] Kurt Schork, "Serb Forces Said to Lift Siege of Kijevo," *Reuters*, 3 July 1998, Relief Web Web site, http://www.reliefweb.int, 16 June 2000.

[119] Michael Ignatieff, *Virtual War: Kosovo and Beyond*, New York: Metropolitan Books, Henry Holt and Company, 2000, 107.

[120] Ibid, 107 and 108.

[121] MG John P. Abizaid (Briefing), "1st Infantry Division Operations in Kosovo," Alexandria, VA: Institute for Defense Analyses, 1 September 2000.

[122] Igantieff, 108.

- As mentioned previously, NATO and the U.S. did not have forces on the ground in Kosovo during the height of the conflict when the disruption of the power grid was beginning to take place. KFOR troops did, however, eventually deploy to the area and, as such, have gained experience dealing with the impacts of disrupted power grids. Knowing little more than that the electricity had been degraded, U.S. forces prepared to go into Kosovo in a self-contained fashion.[123] This had implications for the type and degree of logistics support needed for the U.S. troops.

- Camp Bondsteel was built from the ground up and could not rely upon local electricity sources. After about a month, civilian contractors were able to make repairs to the local power grid and establish a link so that some power could be drawn from towns in the area.[124] These supplies were not nearly sufficient to support the needs of the camp, so U.S. troops continued to depend heavily on generators as their main power source.[125]

- The disruption of power had and continues to have numerous impacts on non-combatants in Kosovo. The following illustrate some of the ripple effects experienced:

    - Food supplies were affected by the lack of power. In the summer of 1998, the town of Malisevo was surrounded by wheat fields that could have been used to provide bread to the many displaced people in the area. This could not be done, however, because the absence of power prevented the milling necessary to process the wheat.[126]

    - In other instances the ability to provide medical care was also hindered. In the same town of Malisevo, a generator was requested in order to be able to sanitize medical equipment.[127] A doctor in the town of Cirez, during autumn of 1998, said "he needed to work at night to cope with the volume of patients he was seeing, but as the health center had no electricity or lighting he was unable to" do so.[128]

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[123] Correspondence with BG (Ret.) David Grange, 29 August 2000.
[124] BG (Ret.) David Grange (Interview), 8 September 2000.
[125] Ibid.
[126] UNHCR Belgrade, "UN Inter-Agency Update on Kosovo Situation Report 46," UN High Commissioner for Refugees (UNHCR), 24 July 1998, Relief Web Web site, http://www.reliefweb.int, 16 June 2000.
[127] Ibid.
[128] "CARE— The Kosovo Winter Emergency Project," *CARE*, 29 September 1998, Relief Web Web site, http://www.reliefweb.int, 16 June 2000.

- The lack of power had a major impact on the availability of drinking water. Many refugees returning to their homes at the end of the summer of 1998 faced repairing not only their homes, but also dealing with no electricity and no access to clean drinking water. Electricity was needed to run the pumps necessary to provide running water.[129]

- No running water, due to no power, had additional impacts on the health of the Kosovo population. One example of this was noted by a Kosovo DART water/sanitation officer who said "Returnees without electricity are using ropes and buckets to get water from wells, which has the potential of introducing contaminants into the wells."[130] Water can be considered a likely contributing factor in the World Health Organization's reports of high rates of intestinal diseases[131] and other reports of more than 6000 cases of infectious disease and 78 fatalities by the end of August 1998.[132]

- There is also the potential for hostilities to be further fueled if electricity is not uniformly restored to a locale. A situation where something like this could have erupted was in the village of Leocina where the Serb enclave's power had been restored, but the ethnic Albanians' had not.[133]

▪ The Kosovo conflict not only resulted in ethnic Albanian refugees, but ethnic Serbs who were displaced or otherwise chose to leave. This had an impact on electrical power in Kosovo, since Serb Kosovars often held important positions, such as specialists and skilled workers in utilities, industry, and administration.[134] Because Serbs had dominated these types of positions for years, there were no ethnic Albanians with experience to assist in rebuilding and restoring utilities, such as electricity.

▪ One of KFOR's major objectives included providing support to the United Nations Mission in Kosovo. KFOR assisted UNMIK in providing humanitarian

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[129] "UN Inter-Agency Update on Kosovo Situation Report 49," UN High Commissioner for Refugees (UNHCR), 31 July 1998, Relief Web Web site, http://www.reliefweb.int.
[130] "USAID/OFDA Kosovo DART Update for November 10," U.S. Agency for International Development (USAID), 10 November 1998, Relief Web Web site, http://www.reliefweb.int.
[131] "UN Inter-Agency Update on Kosovo Situation Report 57," UN High Commissioner for Refugees (UNHCR), 26 August 1998, Relief Web Web site, http://www.reliefweb.int.
[132] "UN Inter-Agency Update on Kosovo Situation Report 58," UN High Commissioner for Refugees (UNHCR), 28 August 1998, Relief Web, http://www.reliefweb.int.
[133] "Kosovo DART Update for November 10."
[134] "War Impact: The Extent of Damage," *Economic Reconstruction and Development in South East Europe*, European Union/The World Bank Web site, http://www.seerecon.org/Kosovo/KosovoWarImpact/WarImpact-Kosovo.htm, 7 April 2000.

assistance to Kosovar citizens, made necessary by the destruction of homes and key infrastructure.[135] The infrastructure necessary to provide heat was of particular importance with an approaching winter. Again, KFOR assisted UNMIK in the restoration of electrical power and heating capabilities, including the supply and management of "heavy oil to assist in running critical and strategic public utilities — to urban heating plants in Pristina, Djacova, and Mitrovica; to the electric power plants; and the major hospitals of Mitrovica and Pristina."[136] Although the supply of oil was intended as temporary support to UNMIK, KFOR had supplied 6,200 tons by the beginning of the year 2000.[137]

- Another impact has been the need for and degree of outside assistance sought after the end of the conflict to not only make repairs to power lines, transformers, and power plants, but also to restore coal production. The European Union contributed "an international management team to help run Kosovo's two main power stations and carried out repairs and supplied spare parts and vital chemicals for these power stations as well the coal mine that supplies them."[138] In order to better prepare for winter, Task Force Kosovo, established by the European Commission, spent 9 million EUR to buy fuel and equipment to run the power plants and take care of necessary repairs.[139]

- With such efforts, both of Kosovo's two main power plants were running and rates of production were recorded to have risen from 120 megawatts to 500 megawatts.[140] Still, as of January 2000, 100 megawatts of power was being imported from Serbia, Macedonia, and Albania.[141] At this time, Kosovo had also reached an agreement to import 60 megawatts of power from the Public Power Corporation in Greece.[142] The immediate transfer of this power could not begin, however, due to

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[135] General Dr. Klaus Reinhardt, "KFOR and UNMIK: Sharing a Common Vision for Kosovo," *NATO's NATIONS and Partners for Peace*, January 2000, 14.
[136] Ibid, 15-16.
[137] Ibid, 16.
[138] European Commission, "Kosovo One Year on the European Contribution," *Press Release*, Memo/00/12, 8 March 2000, http://www.europa.eu.int, 7 April 2000.
[139] "Kosovo Gets Power Plan for Winter," *Press Release*, Pristina: 18 September 1999, European Commission and World Bank Web site on Economic Reconstruction and Development in South East Europe, http://www.seerecon.org/PressReleases/press990918.html, 7 April 2000.
[140] UN Interim Administration Mission in Kosovo, "Pristina Central Heating Plant."
[141] Elena Becatoros, "Electricity for Power-Strapped Kosovo Held up by Infrastructure Concerns," *Associated Press*, 29 January 2000, Albanian Net Web site, http://www.alb-net.com/albsa-info/2000-January/000072.htm, 28 August 2000.
[142] "Greece to Supply Electricity to Kosovo," Athens, Greece, 11 January 2000, Albania Net Web site, http://www.alb-net.com/pipermail/albsa-info/2000-January/000027.html, 28 August 2000.

concerns about the ability of the power grids of Macedonia and/or Albania to handle this transmission.[143]

b. Transportation Network

Similar to the power grid, the transportation network in Kosovo likely also suffered from the neglect caused by poor economic conditions in the years prior to the conflict. Being inland, Kosovo does not have its own seaport facilities, but it does have rail and road networks, as well as at least one airport in Pristina.

In contrast to their approach to the power grid, the KLA and Serbs both exerted control over the ground transportation networks. Both would establish checkpoints along major roads in efforts to exert control over areas and hinder freedom of movement. As early as May 1998, the KLA had closed the major Pristina-Pec highway.[144]

The Serbs in particular attempted to exert control over various aspects of the transportation network. "The police and the Yugoslav Army, with their posts, police stations, and barracks dispersed across Kosovo, are dependent on the conditions of roads— which are susceptible to attacks and ambushes— for supplying these posts."[145] Having a great dependence on tanks and armored vehicles, the Serbs also relied on the rail system for transport into Kosovo.[146] In addition to facilitating logistics, the Serbs also used their control over transportation networks to their advantage. In 1999, they first focused on the area surrounding Djakovica with the goal of controlling and blocking KLA infiltration routes through the mountains adjacent to the Albanian border.[147] They also concentrated on villages and cities near the border and along major transportation arteries in a systematic effort to drive the ethnic Albanians out of Kosovo.[148] To facilitate the movement of refugees, the Serbs further organized the use of the trains and cleared road routes and provided soldiers "at key intersections to control movement."[149]

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[143] Becatoros, "Electricity for Power-Strapped Kosovo."
[144] Kurt Schork, "Serbian Blockade of Kosovo Causes Severe Shortages," *Reuters*, 19 May 1998, Relief Web Web site, http://www.reliefweb.int, 15 June 2000.
[145] "Kosovo Background."
[146] "Belgrade Moves Tanks by Rail into Kosovo," *Agence France-Presse*, 16 March 1999, Relief Web Web site, http://www.reliefweb.int, 16 June 2000.
[147] Kifner, "Horror by Design."
[148] Ibid.
[149] Ibid.

Except for one mention, no information was found in reference to the use of or control over airport facilities by either the KLA or Serbs. However, when KLA attacks were able to stop the movement of goods along the Mitrovica-Pec highway, the Serbs were forced to supply its border troops using helicopters.[150]

NATO's air campaign clearly indicated an effort to disrupt transportation networks in both Kosovo and FRY. Bridges in particular were targets because of their importance as links in re-supply and reinforcement routes for the Serbs. The attacks also damaged Serb airfields, along with "80 percent of the Serb's Mig-29s, about 30 percent of the Mig-21s, 35 percent of the Galeb fighter-bombers and 70 percent of the helicopters," in order to remove them from the combat equation.[151]

The following are some of the impacts experienced due to the disruption of and control exercised over the transportation network in Kosovo and FRY.

Air. When NATO began its air campaign in March 1999, it assumed a position of air superiority. This was accomplished without the use of airfields and facilities in Kosovo. NATO used its own aircraft carriers and U.S. Air Base in Aviano, Italy to launch air strikes, perform maintenance on aircraft, and provide the necessary air traffic control capabilities. Also, with no troops on the ground in Kosovo, NATO had to rely on airborne forward controllers, instead of having air strikes called from the ground.[152] In addition to hitting many of its targets, the air campaign also may have had an impact on FRY's ability to use certain military assets. "Figures however cannot show the extent to which Yugoslav tanks and other assets had to remain immobile to avoid the onslaught. As they were immobile, they couldn't be used."[153]

Even though NATO established superiority in the air, the Serbs used a number of approaches to try to minimize the movement of NATO planes and mislead NATO into bombing the wrong targets. First, the Serbs used missile and anti-aircraft fire, which contributed to keeping NATO planes flying at over 15,000 feet, [154] making target identification and accuracy more difficult. Second, "[o]n the hillsides outside Aviano,

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150 "Kosovo Background."

151 Linda D. Kozaryn, "NATO Pummels Serb Military, Damage Toll High," *American Forces Information Service*, DefenseLINK Web site, http://www.defenselink.mil/news/May1999/n05201999_9905204.htm, 28 August 2000.

152 Ignatieff, 99.

153 Lord Robertson of Port Ellen, "NATO Air Strikes."

Yugoslav amateur spotters, working radio receivers, were listening to pilots take off and then using their cell phones to inform Belgrade of incoming strike patterns."[155] As yet another countermeasure to NATO air power, the Serbs took steps to mislead NATO's targeting and bombings. For example, "[t]hey built fake bridges and applied heat reflecting camouflage paint to the real ones so as to throw-off target acquisition radars."[156] Finally, although not a military activity, civilian protesters on bridges in Belgrade proved effective in protecting these bridges from NATO bombs.[157]

When the U.S. KFOR troops arrived in Pristina, the airport was slightly damaged and its Air Traffic Control capabilities were inoperable.[158] An estimate on what it would take to restore this facility was 10 million EUR within two years.[159]

Land. The ability for a military operation to exert control over the use of ground transportation networks can be of strategic importance. During the Serb's first offensive against the ethnic Albanians in 1998, they failed to seal off Kosovo's borders with Albania and Montenegro. By not doing so, the Serbs created the opportunity for KLA members to blend in with civilian refugees and make their escape.[160] Having learned their lesson, the Serbs focused on gaining control of the borders and main transportation routes during their second offensive in 1999.

Civilians were affected by the conditions of the ground transportation network. During the period when the KLA and Serbs were vying for control, their checkpoints and attacks along major roads hindered the movement of civilians. Ethnic Albanians were particularly suspicious of Serb police and were thus reluctant to use a route with Serb police checkpoints. Refugees and displaced persons improvised with respect to transportation, using tractors pulling carts, horse and wagons, buses, walking, etc. KLA attacks along the Pristina-Pec highway also disrupted the transport of supplies, resulting in bread and flour shortages in Djakovica.[161] HROs and NGOs encountered difficulties in

[154] Ignatieff, 97.
[155] Ibid, 97.
[156] Ibid, 105.
[157] Ibid, 139.
[158] Correspondence with BG (Ret.) Grange.
[159] International Management Group, 8.
[160] Michael R. Gordon and Thom Shanker, "How Yugoslav Military Planned and Mounted Kosovo's Ravaging," 29 May 1999, Albania Net Web site, http://www.alb-net.com:443/pipermail/kcc-news/1999-June/000081.htm, 28 June 2000.
[161] Schork, "Serbian Blockade of Kosovo."

delivering aid to those in need, because of "Serb forces turning convoys away from the main highways, forcing them to traverse small difficult roads."[162] In order to assist in meeting the demand for aid, UNHCR had to transfer 10- and 20-ton trucks from Belgrade to its Pristina headquarters.[163]

Assessments in Kosovo found the road network less affected by the conflict than by general neglect. Even so, road and bridge conditions placed limitations on KFOR's route options into Kosovo. It was believed, however, that the routes used to enter the U.S. sector of Kosovo from Macedonia may have experienced less damage than those closer to the Serb border.[164]

The condition of the roads and bridges did contribute to U.S. delays in occupying certain areas of operation and in the logistics necessary to ensure reliable access to supplies.[165] An Irish Transport Company was brought in under the control of KFOR headquarters in Pristina to provide necessary means for the transportation, at first by truck and then by rail, of military and humanitarian organizations' supplies.[166] The types of trucks used for the transport of supplies had to be adjusted in order to accommodate the road conditions, particularly the minor roadways in Kosovo.[167] The disruption of the bus and rail systems has also been mentioned as impacting the KFOR, since military assets were then needed to compensate for the fact that the normal flow of goods, services, and people could not occur.[168]

"The military force had several primary tasks. The first one was to make sure that routes of entry were safe. That meant demining, taking out booby traps, taking explosive charges from bridges."[169] Such efforts were to prevent delays in movement and expand

[162] Office of U.S. Foreign Disaster Assistance (OFDA), Bureau for Humanitarian Response (BHR), U.S. Agency for International Development, "BHR/OFDA's Information Fact Sheet #6— Kosovo Humanitarian Assistance," U.S. Agency for International Development (USAID), 18 September 1998, Relief Web Web site, http://www.reliefweb.int, 16 June 2000.
[163] "USAID/OFDA Kosovo DART Update for November 9," U.S. Agency for International Development, 9 November 1998, Relief Web Web site, http://www.reliefweb.int, 16 June 2000.
[164] BG (Ret.) Grange (Interview), 8 September 2000.
[165] Correspondence with BG (Ret.) Grange.
[166] Capt. John Pendergast, "The Irish Transport Company," *NATO's NATIONS and Partners for Peace*, January 2000, 38.
[167] Pendergast, 38.
[168] Abizaid (Briefing), 1 September 2000.
[169] "Operation Joint Guardian Kosovo Force (KFOR)," Federation of American Scientists Web site, http://www.fas.org/man/dod-101/ops/joint_guardian.htm, 6 July 2000.

the number of options available for movement.[170] Engineers associated with KFOR troops were reported as having to devote extensive work to secondary roads.[171] Some roads and bridges in particular needed repairs because of their inability to support too many heavy U.S. vehicles.[172] KFOR assisted in the rebuilding of "200 kilometers of roads and six bridges."[173] Four million EUR were also needed in order to purchase equipment prior to the onset of winter for emergency repair of the roads and snow removal.[174] KFOR also assisted in the restoration of "the railway network, providing critical freight and passenger services between major Kosovar cities."[175]

Bridges were a key target of NATO in order to disrupt Serb lines of communication and their capability to reinforce and re-supply. The destruction of bridges affected the daily lives of civilians by making movement from one side to the next for work or shopping more difficult and time consuming. When three bridges in the city of Novi Sad were destroyed, initially the only way to cross the Danube river was "on a barge-like ferry pushed by two motorboats."[176] Indeed, nearly a year after the bombing there was only a pontoon bridge, sometimes resulting in a mile of cars waiting to use the bridge at any one time.[177] Barge traffic on the Danube was also blocked by the debris from the bridges, interrupting millions of dollars in trade between countries along the river.[178] Ripple effects were also created in the disruption of other infrastructure services, because the bridges "also carried electric, gas, and water lines."[179] The estimated costs for removing the debris and rebuilding just these three bridges was estimated at $25 million and $100 million, respectively.[180]

Kosovo's rail network received funds and assistance from other countries to pay for repairs. "Germany, Sweden, and the EU have dedicated funds to the overall repair of

[170] Correspondence with BG (Ret.) Grange.
[171] Ibid.
[172] Ibid.
[173] Reinhardt, 15.
[174] International Management Group, 8.
[175] Reinhardt, 15.
[176] Anne Swardson, "Bombed Bridges Divide Serbian City, Government," *The Washington Post*, 4 April 2000, A25.
[177] Ibid, A25.
[178] Ibid, A25 and Ignatieff, 141.
[179] Swardson, A25.
[180] Ibid, A25.

the railway network including the signal system and railway workshops."[181] Train engines were obtained from Germany and France.[182] When a multi-ethnic train service began in December 1999, UNMIK police and KFOR maintained a presence on trains and at stations for security purposes.[183]

The intent of bombing targets such as infrastructure was, at least partially, to influence the Serb public's opinion against the Milosevic government. Indeed, prior to the NATO air strikes, there were segments of the population in Serbia that opposed Milosevic. Quite to the contrary, however, the public rallied behind Milosevic after at least the initial bombings.

3. Insights from Experience with Infrastructure

Cause of Damage. Overall, because of general neglect, it is not always easy to distinguish the extent to which the Serb and KLA fighting and NATO air campaign may have had an impact on Kosovo's power grid. In truth, it was likely a combination of the two. In July 1999, a follow-up to the European Commission's previous assessment found that 617 units of the electricity distribution network had been damaged and estimated that it would cost 9.6 million EUR to restore the damage done to the power grid in Kosovo.[184] The damage inflicted during the course of the military activity in combination with this neglect, however, does make the job of repairing and restoring Kosovo's electrical grid more difficult. For example, post-conflict economic growth in Kosovo has been "further compounded by the poor state of the infrastructure, inadequate energy supplies and depleted capital stock."[185] Being able to identify the cause of damage to infrastructure may prove important when linked to discussions on who should have the responsibility for its restoration.

[181] United Nations Interim Administration Mission in Kosovo, "Multi-ethnic Passenger Train Started Running in Kosovo," *Press Release*, 30 December 1999, United Nations Web site, http://www.un.org/peace/kosovo/press/templ.pr.120.html, date unknown.
[182] Ibid.
[183] Ibid.
[184] International Management Group, 68.
[185] "Information on Kosovo.".

***Targeting*.** NATO established a multi-phase process for identifying and vetting potential targets during its air campaign. This process included:

- The daily creation of target folders;
- The use of UAV capabilities to obtain additional photos of the target;
- The selection of the best weapon for a target;
- The evaluation of impacts based on grades of collateral damage;
- The assessment of a target, based on the law and the Geneva Conventions.[186]

The institution of similar processes for deliberating on targets may prove useful in future conflicts in order to ensure that the impact of destroying a target is better understood, especially when that target is infrastructure.

Despite this conscientious targeting process, the NATO allies were not always unanimous in their opinions on target selection. Indeed, infrastructure-related targets appeared to cause particular concern. "The British, for example, believed that the bombing of the Serbian TV and the power grid constituted potential violations of the Geneva Conventions, and that the adverse diplomatic and political consequences of these strikes outweighed their military advantages. So no British pilots took part. Similarly, the French government refused to take part in strikes against Belgrade bridges and managed to dissuade other allies from taking them all down."[187]

Accuracy. The best targeting process in the world, however, does not ensure accuracy. NATO's air campaign experience in Kosovo had several factors that had the potential to impact accuracy, despite the use of precision munitions. Because of policy and the existence of Serb missiles and anti-aircraft fire, NATO pilots flew their missions above 15,000 feet. Some might view a contradiction between the goal of minimizing non-combatant casualties and collateral damage while flying at high altitudes.[188]

NATO's bombing campaign also relied on forward air control because of the absence of troops on the ground to verify targets. This raised a difficulty, because "NATO pilots don't train to fire munitions from high altitudes without ground forces."[189] As a worse case scenario, this could have contributed to the bombing of the wrong target or unintended collateral damage. With the likelihood of future missions that will not

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[186] Ignatieff, 100.
[187] Ignatieff, 207.
[188] Ibid, 62.
[189] Kozaryn, "NATO Pummels Serb Military."

allow for the deployment of ground troops, it would prove useful to plan and train for forward air control and high altitude in order to be prepared for this type of contingency.

Weapons Effects. Graphite bombs were used by NATO in order to bring about disruptions in the Yugoslav power grid for limited time periods. However, once it was decided that a more lengthy or permanent disruption was needed, the power grid was struck with a more powerful munition. The NATO multiple air strikes on the Yugoslav power grid illustrated that the use of different munitions can produce a specific desired effect in support of the overall mission.

Responsibility for Restoration. During the course of the NATO air campaign, three bridges were destroyed in Novi Sad, Serbia. After the end of the conflict, there seemed to be confusion and disagreement over who should pay for the repair of these bridges. The position of the Serbian government was that the removal of debris in the Danube and the construction of new bridges should be paid for by those who caused the damage (i.e., NATO, U.S., European Union).[190] With the city unable to pay due to lack of funds, the Serbian government unwilling to provide the funds and, in at least one case, government efforts to prevent the entrance of Austrian engineers into FRY to assess damage and propose solutions, the people of Novi Sad still lacked reliable means for crossing the river nearly a year after the bridges were first destroyed. While it is likely that the delays were at least in part political, this situation does raise some important issues for consideration if infrastructure is going to be targeted in the future.

More Than Physical Damage. During the course of the conflict, many Serb Kosovars who had held key jobs in industry and utilities decided to leave Kosovo. If people like this, with the knowledge and experience in operating and managing key systems, such as a power plant or railway, do not survive or return at the end of the conflict, the restoration of services may be further delayed.

Night Vision Devices. U.S. F-14 Tomcat and F-18 Hornet pilots used night vision devices while flying missions over Kosovo. Using night vision goggles were considered a major enabling factor that allowed pilots "'to fly virtually every day and every night.'"[191]

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[190] Swardson, A25.
[191] Linda D. Kozaryn, "Naval Aviators Claim the Night," *American Forces Information Service*, DefenseLINK Web site, http://www.defenselink.mil/news/Jun1999/n06241999_9906246.htm, 28 August 2000.

This is a particularly interesting insight to note, given that NATO pilots had only recently begun using these devices.[192]

Ripple Effects. The disruption of infrastructure in Kosovo and FRY had a number of secondary effects. Power outages (particularly those that were prolonged) had negative implications for the supply of certain key foods, such as flour and bread, access to clean drinking water, the occurrence of certain types of disease and the ability to provide adequate medical care to non-combatants. Destruction of ground infrastructure and disruption of waterways hindered, and in some cases completely prevented, the flow of goods and services. Oftentimes, other infrastructure, such as gas, electricity, and water, were co-located with bridges and roads, so their destruction also translated into the disruption of additional types of infrastructure.

Neighboring Areas. Although not really touched upon in the above case study, the condition of the infrastructure of Albania and Macedonia did have an impact on Kosovo, particularly during the aftermath of the conflict. NATO forces deployed to both of these areas to support the humanitarian relief efforts for Kosovar refugees. In support of these efforts, the forces needed to make emergency repairs to roads, airfields, and other infrastructure. In addition, the types and amounts of support to care for the refugees was immense. Eighty U.S. military trucks and 30 State Department trucks were shipped to Albania in order to transport supplies from air- and seaport facilities to the refugees.[193] The U.S. also flew "ten missions daily by C-130 aircraft from Italy to Tirana, and taking supplies from there to the borders by helicopter."[194]

Concerns about the conditions of the power grids in Macedonia and Albania also posed problems. Not being able to rely on the use of these power grids for the transmission of electricity prevented Kosovo's import of electricity from Greece.

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[192] Ignatieff, 109.
[193] "Operation Shining Hope, Operation Sustain Hope/Allied Harbor, Operation Provide Refuge, Operation Open Arms," Federation of American Scientists Web site, http://www.fas.org/man/dod-101/ops/sustain_hope.html, 6 July 2000.
[194] Ibid.

D. Commonalties in the Impact of Infrastructure Disruption

One of the most interesting things about the three case studies in this report is that they are all very different from one another in terms of the combatants involved, the intensity of the conflict, and the types and degree of effort that were expended to control the power grid or transportation network. Despite these differences, some general commonalties do emerge that are worth consideration in light of the likelihood that future conflicts will deploy troops to an area where the infrastructure has already been degraded, or a decision has been made that control over the infrastructure could be used to one's military advantage.

1. Control of Infrastructure

In various ways, combatants in each of the case studies attempted to establish their control over certain aspects of the infrastructure in their specific area of operation. Two of the cases made initial moves to eliminate their opponent's air assets by striking airfields, airplanes, and helicopters in order to gain positions of air superiority throughout the conflict. Roadblocks and checkpoints were also used to slow movement and maintain control over who had access to certain areas.

2. Countermeasures

Even though combatants were able to establish air superiority or checkpoints that controlled access on a particular transportation artery, these combatants' foes were equally innovative in using approaches designed to erode the exercising of superiority or control over infrastructure. This was particularly the case with respect to air assets. Chechens used techniques to intimidate Russian pilots in the hope of grounding Russian airplanes, thus saving, at least temporarily, Chechen targets. The Serbs also used methods of decoy and camouflage to mislead NATO pilots and protect key infrastructure assets, such as bridges. The lengths to which these combatants were willing to go in order to erode their opponent's control over or ability to disrupt infrastructure signals the recognition that the continued functionality of key infrastructure is vital to a military operation.

3. Logistics

In one way or another, logistics was affected, if not hindered, in each of the case studies by poor infrastructure conditions or the efforts of other combatants to control the infrastructure to their advantage. In the future, logistics systems will be strained by the increased demands of MOUT. The poor condition or blockage of airfields, railways, port facilities, and road networks will increase the coordination and time necessary to move supplies and personnel to where they need to be. For example, in a situation with only one runway operational, only a certain number of airlifts can be made into that facility in any given day. The absence of power also places additional demands, such as water, food, generators, etc., on a logistics system already strained by the urban fight and the limitations of the transportation networks to support the necessary inflow and outflow for reinforcement, re-supply, and support of humanitarian aid efforts for non-combatants.

4. Ripple Effects

As seen from the case studies, the disruption of a power grid or transportation network is more than what it appears at face value. The lights will go out and the bridge may no longer be of use, but there are many additional ripple effects. Power outages contribute to shortages of clean drinking water, the inability to process certain critical foods such as flour, increasing rates of disease, and difficulty in providing adequate medical care. The destruction of a bridge removes an option for movement that disrupts daily lives and may also be associated with the disruption of additional infrastructure, which has been co-located with the bridge. All of these ripple effects have a tremendous impact on non-combatants, but combatants too find themselves limited in access to clean water, exposure to disease, or options for movement. Furthermore, depending on the method and degree of permanence, the initial disruption of infrastructure and its associated ripple effects have both immediate and long-term consequences for the military operation and particularly non-combatants.

5. Neighboring Areas' Infrastructure

Because of the demands of the operation and/or the condition of the infrastructure in the area of conflict, combatants may be forced to consider the use of neighboring areas' infrastructure. The combatant, therefore, needed to assess not only the condition of infrastructure in Kosovo, Mogadishu, and Grozny, but also in Kenya, North Ossetia, Albania, and Macedonia. In many cases, these assessments indicated that certain repairs or changes were needed to facilitate their use to support the military operation.

6. Influence over Non-combatants

Although perhaps an oversimplification, in each of the case studies there seems to have been a miscalculation with respect to influencing the support of non-combatants. In there own ways, each of the non-combatant groups displayed a strong tendency to unite when faced with an outside threat, even though prior to the conflict they were not pre-disposed to do so. Under these circumstances, Serbs, who previously were not strong supporters of the government, rallied behind Milosevic or at the very least did not create the desired groundswell of opposition that would influence his presidency. The Russians had a similar experience in which their bombing of Grozny quickly turned a populace, which had concerns about the Dudayev government, into one that openly protested and sought to block the movement of Russian ground troops on their advance toward Grozny. This instinct appears to have been particularly powerful when the actions taken (i.e., indiscriminate bombing of Grozny or targeting the power grid in FRY) by the military operation were perceived as the unfair targeting of civilians.

IV. MODELING INFRASTRUCTURE AND ITS IMPACTS

Although this study has already taken an important first step by identifying some key characteristics of infrastructure and its impacts, this information will be of limited utility unless it can be realistically incorporated into a format that promotes improved understanding of infrastructure's effects on a military operation and non-combatants, and facilitates its use in analysis, training, mission planning, and mission rehearsal, as well as the exploration of systems and approaches. Models and simulations would be a dynamic and interactive means for portraying and incorporating infrastructure and its impacts, which could be used to look at various approaches to a military operation with the goal of optimizing the outcome for both friendly combatants and non-combatants.

For the purposes of this paper, the more traditional definition of modeling is expanded to encompass two aspects: 1) the algorithms and equations necessary to determine the impacts of infrastructure disruption within a scenario in the model; and 2) the graphical display of infrastructure components and their impacts within the model. The identification and/or development of a set of equations that represents the behavior and impact of infrastructure and its disruption is by far the more complicated of the two. However determining these equations, representing the functional relationships of infrastructure, non-combatants, and military forces, is a necessity in order to use (with any degree of confidence) such a model for the analysis of urban military operations.

Because of the complexity of an urban area and the absence of a capability to present its features in a consistent and revisable format, the ability to simplify the various aspects of the urban environment, including its infrastructure, through a graphical display would also prove beneficial. In fact, two commanders with experience in numerous operations indicated the benefit that could be derived for planning from having a capability to call up and visually display merely the layout of an infrastructure network, such as the power grid, in combination with the terrain and entities of an operation.[195]

Both of the above aspects need to be addressed in order for models to be able to more comprehensively and realistically attempt to represent the impacts of infrastructure and its disruption on a military operation and non-combatants. Doing so will enable greater confidence, reliability, and ease of use of such models for MOUT analysis, mission planning, mission rehearsal, and the investigation of concepts, doctrine, and systems.

This chapter will consist of five sections. First, a brief discussion of the types of models that exist to support the electrical power industry, transportation planners and operators, and the military. The second section will provide an introduction to the Joint Conflict and Tactical Simulation (JCATS), the present force-on-force model most capable for exploring MOUT, and its present and needed capabilities to portray infrastructure and it impacts. Third, a multistage approach to incorporating infrastructure and its impacts into the JCATS will be presented. Fourth, some example Essential Elements of Analysis (EEA) and measures will be offered in order ultimately to be able to conclude something about the "goodness" of improved understanding and being able to plan and train with access to information about infrastructure and its impacts. Finally, some comments will be made about the data and software to support such M&S activities.

A. Models for Consideration

1. Force-on-Force Models and Simulations

Force-on-force models and simulations provide the opportunity to compare the effectiveness of two forces against one another. The two opposing forces consist of a certain number and certain types of entities (i.e., vehicles, individual combatants, and weapons) and characteristics (movement capabilities, weapons effects, etc.). These entities and characteristics are defined for a particular scenario, which also includes specific terrain and movement paths corresponding to how the two forces will conduct their mission. Force-on-force model runs generate data that can be used to determine force effectiveness and/or the effectiveness of a certain weapon or system. Being able to generate these types of data for different approaches or systems in a given scenario are important to the military for determining the effectiveness of a force or a system. Because of the need for these types of data, the characteristics of infrastructure and its impacts would be most beneficial if incorporated into a force-on-force model.

[195] Interview with MG (Ret.) Ernst and Correspondence with BG (Ret.) Grange.

2. Urban Simulations and Games

The fields of urban planning and development possess their own tools to assist in evaluating development and land use options in an urban area. For those models that are used to perform an analysis of alternatives, a set of relationships or equations must provide the functional foundation. The equations and algorithms that have been developed that represent principles of urban development and economics could prove a useful starting point for being able to capture infrastructure and its impacts on a military operation and non-combatants in a model.

The following are summaries of several urban simulation systems, which could prove of interest in developing an approach to incorporating infrastructure and the impact of its disruption into a model.

- *"CommunityViz™* is a suite of software tools being developed by The Orton Family Foundation designed to assist communities with spatial decision-making and analysis of land-use scenarios."[196] Scheduled for limited release by the end of 2000, this software is an extension to ArcView, a GIS-based software package, which includes a Scenario Constructor, Townbuilder 3D, and Policy Simulator Module. The capabilities of this software allow a user to develop a 3D environment in which alternatives can be examined; to perform impact analyses; and to examine the long-term outcomes of alternatives and policies. Although this simulation is designed and intended to be used for land-use planning, it also illustrates how a 3D urban-based simulation can also possess the functional capabilities to explore different approaches and perform analyses.

- The *UCLA Urban Simulation Team (UST)* has developed its own computer simulation system, specifically for simulating urban areas. This team uses several different models, implementing their methodology to create and manage an urban data base, and view and interact with a visual, 3D environment.[197] Using its system and methodology, the UST has been using "city engineering maps, numerous site visits, and its own internally generated plant, tree and foliage libraries" to construct a 4,000 square mile 3D, virtual model of the Los Angeles area.[198] The purposes of such

[196] "CommunityViz— Community Planning and Simulation Software," Orton Family Foundation Web site, http://www.orton.org/pp/moreinfo.cfm?item...htm, 18 August 2000.
[197] Chan, Jepson, and Friedman.
[198] William Jepson and Scott Friedman, "A Real-Time Visualization System for Large Scale Urban Environments," The Urban Simulation Team's Home Page, http://www.aud.ucla.edu, 14 August 2000.

a model is to facilitate problem-solving for urban planning, urban design, and civil engineering.

- *SimCity*[199] is an educational game developed by Maxis that simulates the development of a city. Based on principles of economics and urban development, SimCity gives the user the opportunity to make decisions, including the design and establishment of power and transportation, on the management of a city and watch how the city develops in terms of population, crime levels, pollution, life expectancy, and aggregate IQ of the city's inhabitants. The ability to have city indicators responding to development and management decisions must be driven by a number of algorithms or equations, reflective of the established principles that form the basis for SimCity. An example of how a decision within the game can impact— both short- and long-term— multiple aspects of a city's health is as follows: if a transportation network is established at too great a distance from a residential area, then the city's inhabitants (Sims) will stop going to work, shopping, etc., which over time may result in an economic downturn and the movement of people away from the city.

3. Industry and Planning Models

The power industry and transportation planning communities also use various models and simulations, which could prove useful for improving understanding in the operation of a power grid or transportation network. Such models are likely driven by algorithms and equations, which reflect established physical and sector principles, that allow for results, such as the re-routing of power, the impact of bottlenecks, etc., to be generated. These model drivers and their outputs merit further exploration to determine their suitability for capturing infrastructure and its impacts on a military operation and non-combatants.

The following are summaries of several industry and network planning models, which could prove of interest in developing an approach to incorporating infrastructure and the impact of its disruption into a model.

- *UPLAN* is a model "for analysis of regional generation, demand, transmission and power markets."[200] UPLAN 's Market Model can be used for long term analysis to identify when and where a new installation should enter into the market. "The model

[199] The summary provided in this section was compiled from: Rusel DeMaria, *SimCity3000: Prima's Official Strategy Guide*, Rocklin, CA: Prima Publishing, 1999.
[200] "UPLAN Capabilities," Energy On-line Web site, http://www.energyonline.com/Restructuring/LCG/uplaspec.htm, 19 September 2000.

evaluates the financial viability of different technologies including combined cycle, combustion turbines and hydro-electric units at these potential locations. The program algorithm automatically determines the location, size and timing of entries throughout the region based on economic viability."[201] Its Optimum Power Flow and Volatility models consist of algorithms that calculate power flows and volatility outcomes, while also managing transmission congestion.[202]

- The *Network Power Model (NPM)* is related to UPLAN and "is based on modeling an entire region with its natural control areas: electric utilities, power pools and exchanges (PX), independent power producers (IPPs), and adjacent reliability areas."[203] NPM's Master Scheduler "includes a load flow model and sub-programs to determine the optimal schedule of resources in each control area using its own protocol."[204]

- Another software program is *Power System Simulator for Engineering (PSS/E).* Developed by Power Technologies, Inc., PSS/E "provides users with power flow, short circuit, dynamic simulation (including long term), optimal power flow, linear network, and small signal analysis."[205]

- The Electricity Market Module (EMM) interacts with the other modules of the National Energy Modeling System (NEMS)[206] to determine electricity prices, fuel consumption, emissions and capital requirements.[207] EMM consists of four sub-modules related to capacity planning, fuel dispatch, finance and pricing, and load and demand-side management. As an example of its functionality, the Electricity Capacity Planning (ECP) "submodule determines how best to meet expected growth in electricity demand, given available resources, expected load shapes, expected

[201] Ibid.
[202] Ibid.
[203] "UPLAN-E Network Power Model (NPM)," Energy On-line Web site, http://www.energyonline.com/Restructuring/LCG/npm2.htm, 19 September 2000.
[204] Ibid.
[205] "PSS/E Brochure," Power Technologies, Inc. Web site, http://www.pti-us.com/pti/software/psse/psse_brochure.htm, 14 August 2000.
[206] "The National Energy Modeling System (NEMS) represents a general equilibrium solution of the interactions between the U.S. energy markets and the economy." NEMS consists of fifteen modules representative of the various energy sectors. "Directory of Energy Information Administration Models 1999," Energy Information Administration Web site, http://www.eia.doe-gov/oss/models.pdf, 19 September 2000.
[207] "Directory of Energy Information Administration Models 1999," Energy Information Administration Web site, http://www.eia.doe-gov/oss/models.pdf, 19 September 2000.

demands and fuel prices, environmental constraints, and costs for utility and nonutility technologies."[208]

- The Transportation Sector Module (TRAN) is also a NEMS module and "incorporates an integrated modular design which is based upon economic, engineering, and demographic relationships that model transportation sector energy consumption."[209] TRAN uses a variety of modeling techniques that are used to provide forecasts "for personal and commercial travel, freight trucks, railroads, domestic and international marine, aviation, mass transit, and military use."[210] The methodologies used by this module address the interconnectivity that exists between transportation networks and their energy sources, including electricity.

- The Transportation Analysis SIMulation System (TRANSIMS) is a system of "models, simulations, and supporting databases that employ advanced computational and analytical techniques to create an integrated regional transportation system analysis environment."[211] The user establishes an urban area, including the transportation network, individuals, and their movement patterns. TRANSIMS then performs these movement patterns, given various modes of transportation and the dynamics of traffic, in order to generate information on vehicle emissions and the performance of the transportation network. "The model forecasts how changes in transportation policy or infrastructure might affect" the movement of individuals.[212] "It can [also] evaluate transportation alternatives and reliability to determine who might benefit and who might be adversely affected by transportation changes."[213]

- The objective of the *Los Alamos National Lab's Urban Security* program, as described in more detail in Chapter II, is "to provide a set of science- and technology-based computational tools with real-time feedback for disaster planning, training, and management in time of crisis and long-term recovery."[214] One of this project's initial foci has been earthquakes and their effects on the electrical power infrastructure of Los Angeles. To do this tools are being assembled that have "a computer-based, multi-layered Geographic Information System (GIS) database coupled to multiple

[208] Ibid.
[209] Ibid.
[210] Ibid.
[211] "TRANSIMS," Los Alamos National Laboratory Web site, http://www.maynard.tsasa.lanl.gov/home.htm, 19 September 2000.
[212] Ibid.
[213] Ibid.
[214] "Urban Security," 1999 Annual Report, LA-UR-99-5554, Los Alamos National Laboratory Web site, http://www.ees.lanl.gov/EES5/Urban_Security/FY99/index.htm, 19 September 2000.

models such as those for seismic ground response, infrastructure damage assessment, and simulations and analysis of infrastructure's operations during emergency response and longer-term recovery."[215] In order to be able to comprehend the performance of a power grid as a system during and after an earthquake, the team has identified the following existing model capabilities as having to be integrated:

1. Generate the "best-possible ground-motion parameters (peak ground acceleration, peak ground displacement, or response spectrum) for the scenario earthquake."

2. Combine ground movement and the fragility of a power grid component in order to determine that component's damage state

3. Use damage estimates to perform engineering analysis of the power grid system and determine the impact of this damage on its performance.[216]

B. JCATS: Present and Needed Capabilities

JCATS is single-entity-level conflict simulation that was developed by Lawrence Livermore National Laboratory. Although primarily used for training, this model is beginning to receive attention from the analytic community as well.

JCATS models various types of ground, air, and sea vehicles, weapons systems, and dismounted combatants. Using the model's terrain editor and a digitizing tablet, different types of vegetation, roads, bodies of water, etc., can be incorporated with three-dimensional, digitized terrain obtained from the National Imagery Mapping Agency (NIMA). An operator sets up a scenario by establishing the force structure (i.e., numbers and types of vehicles and combatants, weapons, etc.) and creating the movement paths and activity nodes necessary in order to reflect a given scenario. JCATS can accommodate multiple combatant sides, each with its own relationship to the rest of the sides in the scenario, and can accommodate civilians and non-combatants.

JCATS is particularly well suited to handle some of the unique characteristics of MOUT. It will model buildings, including their interior walls, windows, and doors. Individual combatants can move (including between floors) and interact within the building interiors. Because of its existing MOUT capabilities, JCATS is presently the force-on-force model most appropriate for the incorporation of capabilities representative of urban infrastructure and its impacts.

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[215] Ibid.

To determine JCATS specific suitability to efforts related to infrastructure, an assessment was conducted to determine if and what aspects of power grids and transportation networks are already resident in the model. As it turns out, JCATS can incorporate, whether through an inherent capability or work-around, many entities and characteristics that could prove useful in the study of infrastructure from a military perspective.

The following are some of the capabilities relevant to power grids and transportation networks that are presently available in JCATS:

Power Grid:

- Outside lighting of a particular area
- Indoor lighting of the entire structure or parts of a structure[217]
- Ability to play night vision devices
- Ability to set probability of line-of-sight blockage (i.e., lighting— day, night, dusk, etc. or as a terrain characteristic)

Transportation Network:

- Roads of various dimensions and surfaces
- Tunnels
- Bridges
- Different types of vehicles
- Ability to block movement

General Use:

- Permanent or temporary obstacles
- Capability for non-combatants to change sides
- Multiple types of weapons, including non-lethal
- Different weapons effects
- Capability to model radius of weapons effect
- Capability for individual to change relationship with others (i.e., a non-combatant could become a combatant).

In general, JCATS is already able to represent many of the physical characteristics associated with infrastructure, such as roads, buses, airplanes, lighting, etc. However, the model does not presently capture factors related to the impact of disrupting

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[216] Ibid.

[217] An area of light may be established such that only one part of the building is lit inside, however, it will be lit in the same area on all stories of that structure.

infrastructure, except perhaps for its capability to crater runways and roads, thereby preventing their use.

The ability to determine the impacts of infrastructure disruption on non-combatants and a military operation requires that algorithms and relationships be identified or developed to realistically reflect these relationships. The following is a sample list of capabilities that would need to be captured algorithmically and integrated into JCATS in order to improve its utility in exploring the impact of power grids and transportation networks on a military operation and on non-combatants:

- Capability to damage a power grid or transportation network with resultant physical effects (i.e., lights go out or no longer can use bridge)
- Capability to portray and disrupt rail transportation
- Determine/indicate the time of disruption
- Cost to rebuild the infrastructure (i.e., in money, time, and personnel/equipment required)
- Impact on non-combatant losses and well-being
- Generate second and third order effects on non-combatants, for example:
  - Food/water distribution centers
  - Non-combatant protests
- Cost to care for non-combatants (i.e. in money, time, and personnel/equipment required).

C. Approach to Incorporating Power Grids and Transportation Networks

While immediately incorporating all aspects of infrastructure and its impacts into JCATS would be preferable, it is more likely that this will need to be accomplished incrementally. The remainder of this section is one approach, encompassing four phases, for the evolution of JCATS to include characteristics and impacts of power grids, transportation networks, and their disruption.

The four phase breakdown of this approach is not intended to convey that they are mutually exclusive or that one phase is more important than the other. Instead, the phases are to represent the reality that certain aspects of digitally incorporating infrastructure and its impacts into a model can be accomplished in a shorter time than others. Ideally, all four should begin immediately, but with the understanding that the identification and development of the algorithms and equations representing the impacts of infrastructure and its disruption are more complex and time consuming than being able to graphically display the physical components of infrastructure. Nevertheless, the identification and development of these mathematical foundations are crucial in order to ensure that what can be graphically portrayed is consistent with the reality of infrastructure and its impacts on a military operation and non-combatants.

1. Phase One— Physical Representation

In order to incorporate a physical representation of infrastructure components into JCATS quickly, changes need to be made to the model to allow for overlays of power grids and transportation networks on top of the terrain and city structure being considered. Various components of the infrastructure (i.e., power stations, power lines, train stations, airports, etc.) could be portrayed in different colors in order to make them more easily distinguishable from one another. Figure 2 contains two JCATS screen captures that illustrate how such overlays might look.

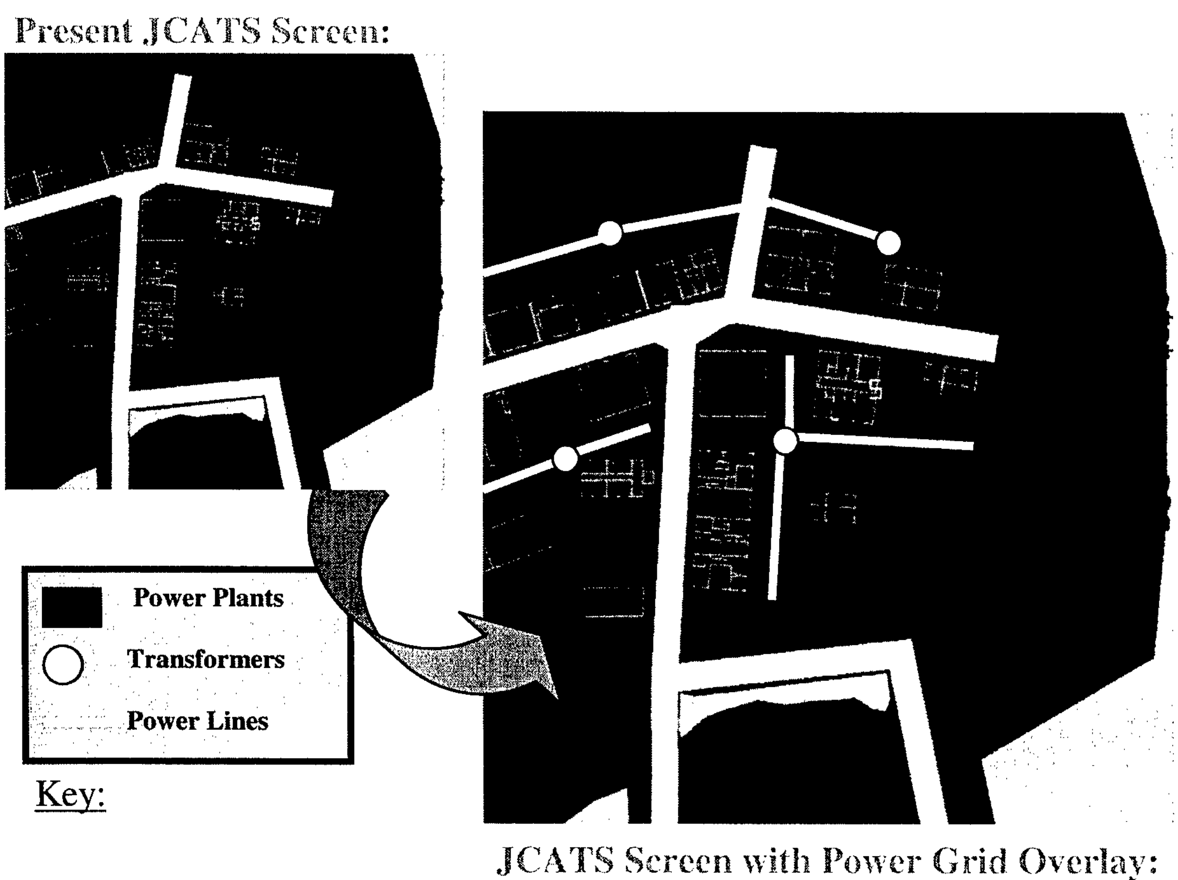

Figure 2. Comparison of Present JCATS Screen Capture and with Power Grid Overlay

This initial capability is intended to build upon the present CAC file function, which provides a commander or analyst the opportunity to have certain directions and instructions related to the mission displayed on the screen as overlays on the terrain in the model. Such a capability would enable a commander to chose to see where the power grid or transportation network is in reference to specific terrain, buildings, or troop positions. Being able to see all of this information in a single view is intended to fill the void in the ability to provide this information in an integrated fashion and assist in planning and mission rehearsal, particularly in instances where the location and condition of infrastructure are important to the execution and outcome of a mission.

Presently, CAD files may be imported into JCATS in order to simplify the process of creating a building, with its associated dimensions, internal layout, and construction, in the model. If Geographical Information Systems (GIS)[218] files were compatible with JCATS, they could be used to provide the geographic location data necessary to be able to produce the desired power grid and transportation network overlays.

2. Phase Two— Accessing Additional Data and Analysis

The next phase is to attach additional information and available analysis to the overlays of the infrastructure and its individual nodes that may be accessed in order to improve understanding. Having access to more information about aspects of a power grid or transportation network would enable a commander to get an improved sense of approaches to control this infrastructure, and how its disruption could impact the military operation and non-combatants.

There may be some way to visually distinguish those infrastructure nodes for which additional information and analysis has been collected and is available. Clicking on an infrastructure node could cause a dialogue box to pop up containing specific types of information about that node. Although military users should have input into the types of additional information they would like to be able to see, some examples of content for these dialogue boxes for a power plant might include: type of plant, age of plant, dimensions, population served, daily output, operational or not. In addition to the

[218] GIS provides the ability to manipulate and create maps by removing and adding categories of information to a map based on their geo-positioning information.

dialogue box of additional information, links could be made to pictures, 3D models, and additional analyses as available. JCATS already possesses the capability to attach pictures to a building in the model, so technically the presentation of these additional types of data may be handled in a similar way.

Figure 3 illustrates how this dialogue box feature with additional information might work. Similar to the capability in JCATS to click on a dismounted combatant and have his line-of-sight graphically displayed, clicking on, say, a particular transformer might create a shaded area representative of the area of the city that would lose electricity if that transformer were destroyed or otherwise disrupted. The ability to display such an impact area would depend upon the output of the types of functional relationship equations that are discussed in Phases 3 and 4.

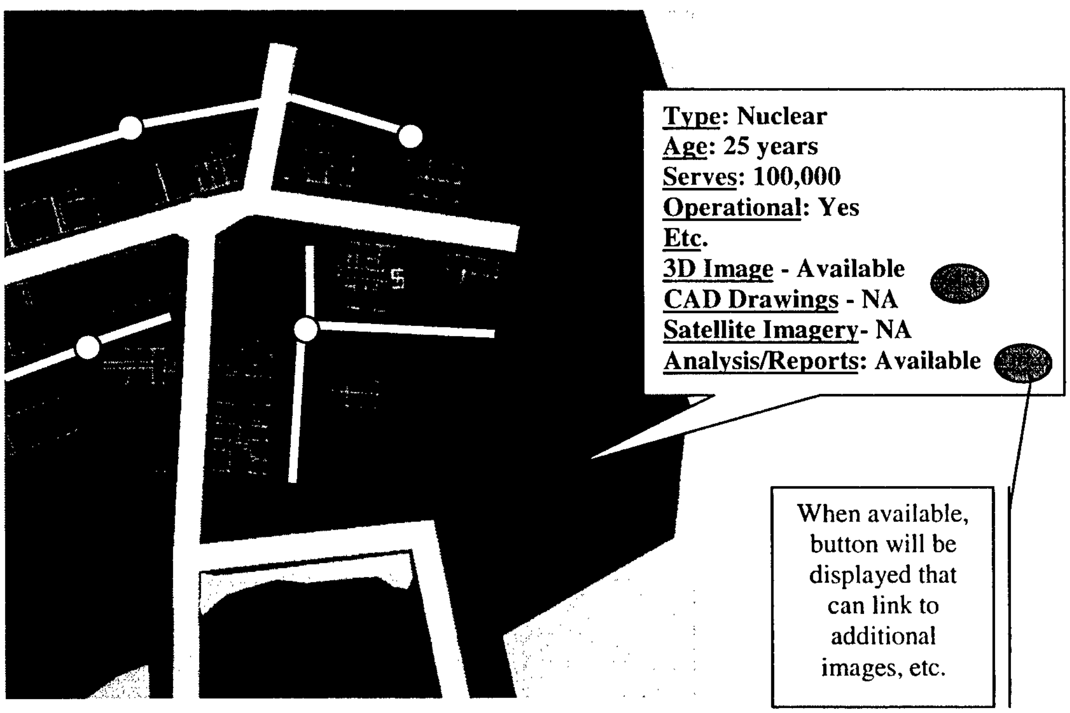

Figure 3. Illustration of Dialogue Box Feature for Additional Information on Infrastructure

3. Phase Three— Infrastructure Entities and Weapons Effects Table Structure

Phase three involves taking an overlay capability in JCATS and having these components of infrastructure incorporated into the model. In this way, the infrastructure would possess characteristics and qualities similar to other entities, which enable interactions to take place within the JCATS model.

Presently, when a terrain feature, such as a road or river, needs to be incorporated into a JCATS scenario, this is done by hand using a digitizing tablet to embed these features into the already imported DTED terrain. Once in the model, certain characteristics — for example, probability of line-of-sight blockage, trafficability, etc.— can be attached to these digitized terrain features, which then have an impact on the running of the scenario. An important advance would encompass being able to use GIS files to import these types of terrain features and then assign their characteristics. For example, a GIS file containing the location of the bridges in an urban area could be imported into the model. As a group, these bridges could then have information and data such as weapons effects, trafficability, etc., assigned.

The initial automatic impacts, which are desired, are essentially a physics and weapons effects issue, similar to what happens already in JCATS when a particular weapon has a specific effect on a particular vehicle, person, etc. Equations specific to the components of a power grid and transportation network need to be identified or developed in order to be able to generate outputs, such as the duration of disruption, population effected, area affected, cost to restore, etc. These equations then govern the types of interactions witnessed when a specific infrastructure target is disrupted using a specific means. For demonstration purposes, Table 3 represents a possible structure for a weapons effects table that could be generated for several types of power grid nodes.

Table 3. Example Structure for Weapons Effects Table for Power Grids

Target	Means to Control	Duration of Service Disruption	Population Effected (& as % of Overall Population)	Area Affected	Cost to Restore Service
Power Plant					
Type 1	Kinetic 1	6 months	300,000/85%	20km²	$300M
	Kinetic 2	2 months	200,000/70%	15km²	$100M
	Non-Kinetic 1	1 week	50,000/50%	5km²	$500K
	Non-Kinetic 2	2-6 hours	20,000/25%	3km²	$45K
	Digital	variable	variable	variable	variable
Type 2	Kinetic 1	3 months	150,000/65%	10km²	$225M
	Kinetic 2	1 month	75,000/45%	6km²	$100M
	Non-Kinetic 1	2 days	25,000/35%	3km²	$300K
	Non-Kinetic 2	2 hours	10,000/20%	1km²	$75K
	Digital	variable	variable	variable	variable
Substations					
Type 1	Means 1- n	Duration x	X Population	X Area	X Cost
Type 2	Means 1-n	Duration x	X Population	X Area	X Cost
Type 3	Means 1-n	Duration x	X Population	X Area	X Cost

4. Phase Four— Accounting for Ripple Effects

The most difficult and time consuming phase will encompass including the types of second and third order effects that can result from the disruption of power grids and transportation networks in urban areas. Ripple effects might include the increased need of combatants and non-combatants for food and clean water, which might become the responsibility of the military if the normal infrastructure that supports food and water is disrupted for purposes of the operation. This might also include psychological factors, to include protests and violent activity by civilians who begin to hold the combatants responsible for disrupting infrastructure service and, therefore, the quality of their daily lives.

How would this work? Let's say that a military operation chooses an approach that uses weapon A to attain control over the power grid. Weapon A results in the power plant being non-operational for six months and impacts an area of the city that contains 150,000 non-combatants. Suddenly, the military will need to establish feeding and clean water distribution centers to assist the non-combatants in this area. These other activities may require the diversion of troops from the mission or require additional personnel and supplies to be brought in. However, using weapon B or approach C to the power grid may have an impact on a much smaller segment of the population and only for 48 hours, therefore minimizing the degree and types of ripple effects with which a military operation would need to get involved.

As more is learned about infrastructure and the impact of its disruption from the examination of MOUT, these ripple effects could appear during the course of a JCATS run in the form of a broadcast box. At this point such an announcement might list the types of ripple effects that might be experienced because of a particular approach taken to gain control of the infrastructure and the resulting types of activities and efforts that might be required of the military in order to mitigate and/or alleviate the impact of these secondary effects. Ultimately, however, a more automated approach to impacts is desired to be resident in the model. This will require a more detailed investigation of historical MOUT examples and the tools and methods used by industry and urban planning to determine the equations and relationships necessary to determine and represent infrastructure and its impacts in the model. In this more automated approach, feeding station icons or protest icons could perhaps pop up on the screen to represent the ripple effects and present the operator with options on the diversion of troops away from their designated role in the mission to those areas most effected by infrastructure disruption.

In addition to merely capturing the more basic ripple effects, it may prove useful, in looking at and comparing various approaches, for there to be a meter or a table that appears at all times on the JCATS screen that cumulatively tracks aspects of the military operation, as well as indicators of the city and non-combatants' health. Indicators might include: projected number of military personnel needed to complete the mission, projected cost of the mission, projected length of the mission until able to turn city back to civilian authority for operation, number of non-combatants under military care, a health index for both the troops and non-combatants, a standard of living index for non-combatants, etc. Having access to these types of information could prove particularly useful during planning by providing a means with which to compare and contrast different options.

Again, the ability to provide such functionality within a model requires the identification and development of algorithms and equations that reflect these relationships between infrastructure disruption, a military operation, and the overall health of the urban area and its non-combatants. The experience and tools of industry and urban development may provide a good start in the development of these model foundations. Efforts to quantify these relationships may be further assisted by HROs/NGOs, which may also possess data and even their own formulas that are used to determine the health, standard of living, and even the types and quantities of supplies that are needed when conducting a humanitarian mission in an urban area where infrastructure has been disrupted. Further investigations of historical MOUT examples may also identify commonalties, which can then be used to create new equations representing the impacts of infrastructure disruption on a military operation and non-combatants.

D. Essential Elements of Analysis (EEA) and Measures

For infrastructure to be more comprehensively assessed as an important factor in a military operation, there is a need for measures against which data can be collected. These measures and the collected data are intended to assess the effectiveness and progress of an operation or an approach with respect to an aspect of infrastructure. Ideally, measures would be useful in both M&S and a real-world operational context. However, certain M&S limitations and obstacles to collecting certain types of data in an operational environment may not always allow for the interchangeability of measures.

The following lists some examples of the types of Essential Elements of Analysis (EEA) and measures that might be considered:

Power Grid—

EEA:

- Extent of damage or interruption of electricity generation and distribution
- Effect on combatants and non-combatants

Measures:

- Number of electricity generation and distribution facilities damaged
- Number of combatants and non-combatants without power
- Time, Cost, and work hours to restore power

Transportation Network—

EEA:

- Degree of successful road, bridge, tunnel interdiction
- Extent of reduction in the movement of people and supplies
- Degree to which troop movement has been impeded

Measure:

- Number of roads, bridges, tunnels targeted, destroyed, repaired
- Time, cost, and work hours to repair roads, bridges, and tunnels
- Amount of supplies delivered and vehicular traffic after interdiction

Appendix A contains a more comprehensive list of potential EEAs and measures pertaining to infrastructure and the impact it can have on both a military operation and on non-combatants. In addition to typical measures that might be associated with a power grid and road, rail, air, and water transportation networks, some additional measures are provided for the EEAs for violent crime reduction and humanitarian assistance. These are included because of the ripple effects that infrastructure disruption can cause, for example, in terms of the amount of basic supplies that are able to reach non-combatants and criminal activity that may be sparked. So, in other words, if the disruption of infrastructure resulted in either of these ripple effects, the military would likely need to respond in order to attempt to maintain some level of overall order in the area of operation.

E. Data and Software Issues

Any efforts to include the characteristics and impacts of power grids and transportation networks in JCATS will only be as useful as the data that are available to support the running of the model. At this point, there does not appear to have been a concerted effort to collect data on infrastructure and its impacts, specifically with respect to a military operation.

Without a doubt, however, there have been and are multiple, ongoing efforts among the military research and operational communities to collect data relevant to various aspects of infrastructure. Data may also exist in the civilian world — for example, the power industry or urban transportation planners. The difficulty that exists is that there is no central repository to turn to in order to find out what efforts have taken place and what types of data have been collected. Another issue of concern, particularly for the use of models, is that the data that are available exist in varied formats, which may additionally rely on multiple software programs that run on specific computer platforms. The absence of a central data repository and uniform or at least complementary data formats, software, and supporting computer platforms is an ongoing obstacle to efficiently and most successfully using models, such as JCATS, for any purpose, including the exploration of infrastructure within a military context.

V. CONCLUSIONS AND RECOMMENDED FUTURE STUDY

The general conclusion of this study is that the disruption of infrastructure can have a profound and wide variety of impacts on a military operation and on the non-combatants. The type and degree of disruption or control exercised over a power grid or transportation network can make a difference in—

- The rate of movement (i.e., due to road conditions, mines, obstacles)
- The number of movement routes available to move troops or supplies
- The speed with which re-supply and reinforcement can take place
- The level of Situational Awareness (i.e., light, no light)
- The amount of assistance (cost and diverted personnel) necessary to address non-combatant needs
- The length of time assistance is necessary to address non-combatant needs
- The cost to restore power or transportation services
- The time to restore power or transportation services.

The corresponding general recommendation is, therefore, that the short- and long-term impacts of infrastructure and its disruption should be considered up front during the planning phase of an operation. By doing so, the goal is to be able to successfully accomplish the mission, while enabling its use to one's advantage, minimizing the negative impact on non-combatants and the number of NGOs and HROs necessary to address their needs, and facilitating the ease and speed with which the military is able to transition control over infrastructure to a civil authority.

A. Conclusions

As illustrated through the case studies, every military operation is unique. To a certain extent, a military operation's experience with the disruption of infrastructure will always be dependent upon the individual circumstances associated with its specific location, combatants, and non-combatants. However, this does not mean that it would not be useful to have a better understanding of the general impact that infrastructure can have on a military operation and on the daily lives of non-combatants, both during and in the aftermath of a conflict. In order to build this type of knowledge, and facilitate its usefulness, these case studies have led to the isolation of a number of areas that merit mention as overarching conclusions and/or considerations.

1. Logistics

Past and present experiences in MOUT have proven that fighting in a city requires more troops, more ammunition, and more supplies, placing increased demand on the military's established logistics system. The key is be able to deliver the right personnel and supplies to the right place, at the right time. This may require the flexibility to adapt to and use the preferred transportation method for long haul — whether it be trucks, railcar, ship, or air — in the region where the troops are deploying. By doing so, the logistics operation can take advantage of that country or region's best developed or least disrupted transportation network — roads, rail lines, rivers, ports, and airports — to re-supply and reinforce, and avoid placing additional stress on or even damaging its less-developed transportation networks, which could ultimately further impact a military operation.

For the successful execution of MOUT, logisticians have specific needs to be able to reach into the city to re-supply and reinforce the troops on the front line. This may be possible using the local transportation network or require more or different modes of military transport vehicles than those planned in order to adapt to the conditions of the infrastructure and address the increased demand of military forces in an urban area. The Russians were unable to do this in Grozny, resulting in shortages of ammunition, food, and water. Their experience surfaced the need for an armored vehicle specifically configured to transport supplies, in order to survive the fighting and deliver goods to troops in the city.

The logistics system must also be conscious of the types of additional demands that the disruption of other types of infrastructure, such as a power grid, can cause. Knowing the typical additional items that are needed when there is no power may allow the logistics system to better prepare for a deployment to a place where the power grid has been degraded or even begin to proactively prepare for these types of needs when a power grid has been designated as a target.

2. Targeting

If, in a military operation, a commander decides to consider the targeting of infrastructure, an established procedure should be put in place to evaluate potential targets. In order to accomplish this, those involved in the targeting procedure need to begin with an understanding of the general types of impacts infrastructure disruption can have on combatants and non-combatants, and any likely associated ripple effects. The types of questions that should be considered during the course of the targeting procedure might include:

- What is the desired benefit to the military operation of disrupting or exercising control over a power grid or transportation network?
- For how long does this disruption or control need to last to accomplish mission objectives?
- What are the weapons, munitions, and approaches available to achieve disruption or control?
- What are the physical collateral damage assessments for each of these options?
- What are expected ripple effects (i.e., short - or long-term, physical or psychological, etc.) of the disruption or control to be experienced by combatants and non-combatants?
- What additional efforts would be needed to mitigate or alleviate ripple effects, who would perform these, and for how long?
- What are the estimated costs to address ripple effects and fund repairs and restoration of service?

The intent of such a procedure is not to argue that infrastructure should never be targeted. Quite the contrary, there have been and will likely continue to be instances when the targeting of infrastructure proves effective in achieving the objectives of the military mission. It is rather to encourage the need for a better understanding of infrastructure so that informed trade-offs can be made when considering target options and the approach to be taken.

3. Targeting Assessment Team

In order to more comprehensively assess information gathered for each target, an interoperable and integrated, targeting assessment team would prove useful. Interoperability of this team would be achieved by drawing its members from all of the Services. The team would also be integrated by including representatives of, for example the infantry to provide a ground operations perspective, even when dealing with the selection of air targets. Since ground troops physically deploy, whether for combat or peacekeeping, the conduct of their mission is greatly influenced by the local conditions of the area of interest. As stakeholders in the overall military operation, ground troops should have a voice in the selection of air targets and the means directed toward these targets. By being an active participant, even in the early stage of what may begin as merely an air campaign, a ground representative may be able to offer targeting recommendations that, in the event of a ground campaign (combat or peacekeeping), would enable troops to more efficiently and quickly complete the mission and transition control to civil authority. There are examples of the lack of such a consideration in recent years, e.g., when agencies responsible for providing analysis on these types of issues have no Army or Marine Corps personnel assigned to them.

4. Civilian Affairs

Unlike the more controversial term, "civil affairs," which is associated with nation-building activities, "civilian affairs" is intended to refer to all activities of the military related to addressing the needs of civilians within an area undergoing or having gone through a conflict. Of particular interest to this study would be those activities of civilian affairs related to restoring the infrastructure services, which civilians depend upon most for the functioning and quality of their daily lives. After all, the ultimate objective at the end of a military operation is to be able to transition assistance responsibilities and control to a local, civilian authority.

In order to ease and facilitate this transition, a military may want to consider the use of troops with specific knowledge and experience dealing with various types of infrastructure. Such troops (most likely a component of the ground forces) would begin by being involved from the beginning phases of an operation. On the one hand, where the deployment is to a location where the infrastructure has been damaged, they could assess its condition; identify critical segments of the infrastructure for repair in order to support the operation and better provide for non-combatants; provide insights on the types of additional supplies that may be needed to compensate for the disruption; and develop a plan for and ultimately coordinate the execution of its restoration. On the other hand, when infrastructure is being considered in the determination of targets, these troops might be able to recommend approaches that will minimize negative impacts for friendly combatants and non-combatants, while still facilitating the successful execution of the mission at hand.

5. M&S

In order to be able to efficiently assimilate and use the vast amounts of information for analysis and planning, a model incorporating infrastructure and its impact would prove useful. To do this, however, there is a need for the development of algorithms and equations representative of infrastructure and its impacts on a military operation and non-combatants. Provided that the appropriate mathematical and scientific foundations are developed to drive this work, a model such as JCATS would provide opportunities to view infrastructure in conjunction with terrain, as well as interactions with other entities within the model. Having these capabilities would allow one to experiment with different approaches to gaining control over or disrupting a component of infrastructure by comparing their impacts on the rest of the military operation and even non-combatants. The inclusion of infrastructure and its impacts in M&S would provide a valuable tool for use in training, mission planning, mission rehearsal, and the exploration of systems and approaches to MOUT.

B. Recommendations for Future Study

The intent of this study was to provide some preliminary research to improve the understanding of infrastructure and its impacts on a military operation and on the non-combatants. Throughout the course of the research, preliminary results have been periodically presented to those with interest in MOUT. It has sparked a dialogue in the community with respect to infrastructure and the idea that there may be different approaches to gaining control of the infrastructure — which will support the objectives of the mission while at the same time have a minimal impact on non-combatants. Inevitably, however, the discussion usually turns to additional or the expansion of topic areas related to the issue of infrastructure and its impacts. Since many of these were beyond the scope of this study, we conclude with a list of some topic area recommendations for future study.

- Additional Infrastructure Networks (communications, gas, water, etc.)
- Additional MOUT Infrastructure Case Studies
- WWII Civil Affairs Experience

- Recent and Ongoing Service Efforts Addressing Infrastructure
- Data and Lessons Learned from Domestic Natural Disaster Experiences
- Data and Lessons Learned from Natural Disaster Response and Evacuation Plans
- Experience and Insights from Urban Planners
- Experience and Insights from Power Industry and Transportation Planners
- Identification of Algorithms Representative of Infrastructure and Its Impacts
- Coordination with NGOs and HROs in Areas with Infrastructure Disruption
- Targeting of Infrastructure and Selectable Weapons Effects
- Coordination with Coalition Partners for Targeting Purposes and the Conduct of Operations with Infrastructure Disruption
- The Adoption of a Civil Affairs Component Focused on Infrastructure from Mission Planning through Restoration
- The Potential for Computer Network Attack on Infrastructure
- International Law Implications
- Psychological Impact of Infrastructure Disruption

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Appendix A

Essential Elements of Analysis (EEA) and Measures

Essential Elements of Analysis (EEA) and Measures

Transportation

1. Road Routes.

EEA:

a. Degree of successful road interdiction.
b. Degree of Successful Bridge/tunnel interdiction.
c. Extent to which movement of people and supplies has been reduced.
d. Permanence of damage.
e. Degree to which troop re-positioning has been impeded.

Measures:

a. Number of bridges/tunnels targeted.
b. Number of bridges/tunnels destroyed/closed.
c. Number of bridges/tunnels repaired/reopened.
d. Number of roads blocked.
e. Number of road repair sites required.
f. Time required to repair roads/bridges/tunnels.
g. Miles of road repairs required.
h. Length of time required to make repairs.
i. Workman hours of repair required.
j. Percentage of routes/bridges/tunnels blocked.
k. Cost of repair for roads/bridges/tunnels.
l. Number of road blocks set up.
m. Route capacities before interdiction in vehicles per day/hour.
n. Actual vehicle traffic count after interdiction.
o. Supply delivery ton-miles before and after interdiction.
p. Troops/troop units repositioned after interdiction.

2. Rail/Air/Water Routes.

EEA.

a. Extent the ability to move people and cargo has been reduced (military and civilian.)
b. What is the military (friendly and enemy) effect of the interdiction?
c. What is the effect on the civilian population?

Measures.

a. For rail, same as for roads above, plus:
Number of rail switch/marshalling yards struck.
Count of heavy weapon systems moved.

b. For Air:

Number and type of Aircraft destroyed.
Number of airfields blocked by cratering.
Number of air terminal facilities destroyed/damaged.
Number of aircraft maintenance facilities destroyed/damged.
Aircraft maintained before and after interdiction.
Materials Handling Equipment (MHE) destroyed.
Airfield capacity (aircraft, people, tons) per hour/day before and after interdiction. (Civil and Military).
Time required to effect repair.
Cost of repair.

c. For Water:

Number of Water-craft destroyed/remaining.
Number of Docking facilities attacked/destroyed.
Number of locks damaged/destroyed.
Number of canals breached.
Route capacities before and after interdiction.
Supply tons delivered before and after interdiction.
Time required for repair.
Cost of repair.

Essential Elements of Analysis (EEA) and Measures

Power Grid

1. Power Plants, Transmission Lines and Sub-stations:

EEA:

a. Extent of power delivery interruption.
b. Extent of power generation interruption.
c. Fraction of intended effect achieved.
d. Degree of unintended effects imposed.

Measures:

a. Number of power plants, sub-stations and transmission facilities struck.
b. Generation capacity before and after interdiction.
c. Number of line breaks.
d. Area denied power.
e. Number of civilians denied power.
f. Number of troop facilities denied power.
g. Number of businesses denied power.
h. Length of time power denied each area.
i. Cost to restore power.

3. Local Distribution and Specific Facilities:

EEA:

a. Extent of damage.
b. Effect on non-combatant population.
c. Effect on opposing forces.
d. Effect on own forces.
e. Degree of intended effects accomplished.
f. Extent of unintended effects imposed.

Measures:

a. Number and length of local line breaks.
b. Number of military and non-combatant people without power.
c. Length of time power denied.
d. Time required to restore power.
e. Cost of power reatoration.
f. Number of friendly units requiring supplementary power supply.
g. Number of businesses denied power.
h. Cost to local economy of business disruption.
i. Number of hospitals denied power, and duration.

j. Number of water treatment and supply facilities affected, and duration.
k. Number of radio and TV stations affected, and degree to which transmission reduced.
l. Number of enemy air defense units denied power.

Essential Elements of Analysis (EEA) and Measures

Evaluation of Civic Action/Civil Affairs Efforts

1. EEA - Violent Crime Reduction.

Measures:

a. Number of murders.
b. Number of rapes.
c. Number of robberies.
d. Number of kidnappings.
e. Number of arson attempts.
f. Number of reported intimidations.
g. Value of stolen property.
h. Value of destroyed property.
i. Number of weapons seized.
j. Number of weapons turned in.
k. Number of non-combatants injured/killed.

2. EEA - Humanitarian Assistance.

Measures:

a. Amounts of blankets, clothing and food and water supplied.
b. Number of persons provided shelter.
c. Sanitation facilities restored.
d. Disease rates before and after operations.
e. Incidence of new disease outbreak.
f. Number of persons visiting distribution points.
g. Non-combatant deaths.

3. Question: "To what extent has or will the disruption to infrastructure increase the negative side of establishing law and order and humanitarian assistance?"

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13. ABSTRACT (Maximum 200 words)

Recent and ongoing military operations in cities and urban areas, as well as the expectation for future conflict and operations in this environment, have led the U.S. military community to focus on improving its understanding of and capabilities in military operations in urban terrain (MOUT). However, despite this interest and the importance of interconnected infrastructure networks to the functioning of a city, there does not appear to have been a corresponding degree of concentration or study with respect to the effects (costs and benefits) of urban infrastructure and its disruption. The study presented in this paper attempts to address this void by expanding the understanding of infrastructure, specifically the power grid and transportation network, and the types of impacts that its disruption can have on a military operation and non-combatants. This study further uses this improved understanding of infrastructure to develop an approach for incorporating a power grid, transportation network, and their impacts into modeling and simulation (M&S). The representation of critical urban environment features, such as infrastructure, in M&S would be an improvement to existing M&S tools, supporting analysis, training, mission planning, mission rehearsal, and the investigation of concepts, doctrine, and systems to enhance U.S. forces' capabilities in MOUT.

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